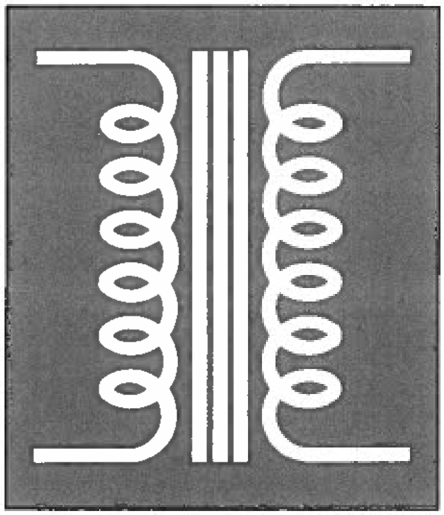
no. 1 in a series

Interchange

solutions to common transformer problems

Q. I am planning a new job which requires a 300 KVA, 3ϕ transformer, several 25 KVA, 1ϕ transformers and a 30 KVA, 3ϕ transformer. This is essentially the same type of installation which our firm completed a year ago. In this installation we received numerous complaints about transformer noise. What causes transformer noise, and how can it be eliminated on the new job?



A. Transformer noise cannot be eliminated. It can, however, be reduced through proper design and assembly, and/or masked through proper consideration of the installation.

The basic cause of transformer noise is magnetostriction: the expansion and contraction of the iron core (laminations) due to the magnetic effect of alternating current flowing through the transformer coils. This produces an audible hum. Magnetostriction may be partially controlled by the transformer design, but it cannot be totally eliminated.

The fundamental sound frequency is twice the power line operating frequency of the transformer (i.e., a 50 Hz transformer produces sound at 100 Hz and a 60 Hz transformer produces sound at 120 Hz). In addition to the fundamental frequency, harmonics are also produced.

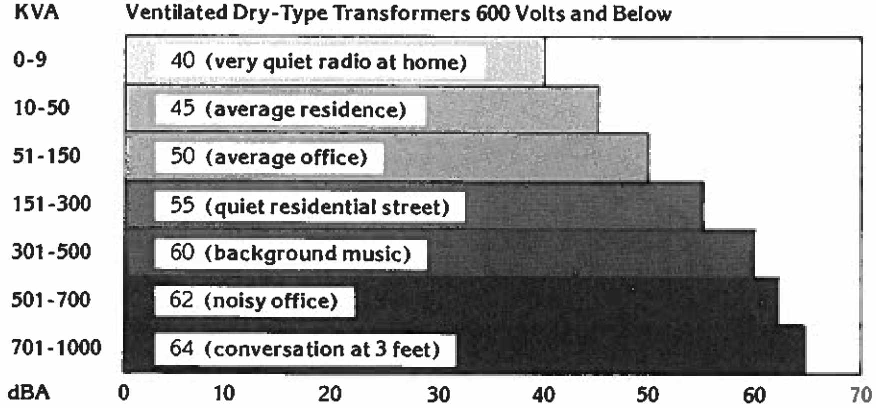
National Electrical Manufacturers' Association (NEMA) Publication ST-20—1972 (R-1978) establishes maximum sound levels for dry-type transformers.*

Since the average office environment is about 50 decibels, depending upon the equipment within the office, the location of a 300 KVA transformer in such an area would produce complaints. The 5 decibels (50db vs. 55db) difference between the normal office ambient sound level and the maximum sound level of the transformer may not seem significant; however, it is recognized that a 3 decibel increase in sound level measurement represents a doubling of the actual sound level, so the 5 decibel increase becomes quite large.

As this example shows, even a well designed transformer can be a problem if it is located without consideration of its surroundings. Transformer noise can be brought under control through proper installation. The following guidelines will help assure you of an acceptable installation.

1. The maximum sound level of the transformer to be used should be compared with the estimated ambient of its location. If it is higher than its estimated ambient, the unit should be relocated.
2. When installing transformers in "people areas," such as office buildings or motels, plan to have at least one "non-people" room between the transformer and the "people area."
3. The mounting surface for a transformer should not amplify the sound level. A general rule of thumb is the mounting base (such as a concrete floor) should weigh at least 10 times as much as the transformer.
4. A corner location should be avoided since the sound will be reflected out into the room.
5. Don't mount units on thin walls, such as plywood or curtain walls. They amplify the noise.
6. The manufacturer's installation instructions should be followed so that any vibration suppression devices incorporated in the transformer design are utilized.

* Average Sound Level in Decibels for Self-Cooled, Ventilated Dry-Type Transformers 600 Volts and Below



All Acme transformers operate at sound levels below NEMA standards and each unit, 30 KVA and larger, is shipped from the factory with vibration isolation pads to help assure you of the quietest installation possible. Encapsulation greatly suppresses noise in units under 30 KVA, and vibration isolation pads are not required.

For information on Acme's complete line of FIVE-YEAR WARRANTED dry-type transformers, circle the reader service number and receive your FREE 1979 Master Catalog. Among other things, it provides answers to 42 basic questions about transformers. Or contact your local Acme distributor.

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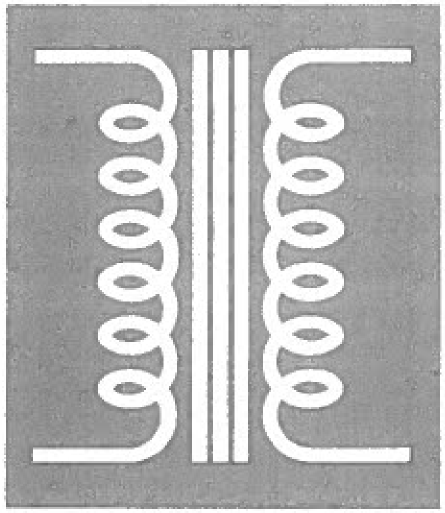
Interchange

no.2 in a series

solutions to common transformer problems

Q. As Chief Electrical Foreman responsible for maintenance of all secondary distribution systems and loads in a large manufacturing facility, I am becoming increasingly concerned over the effects of constant low voltage throughout the system. Exactly what effects does low voltage produce, and how can I compensate for them?

A. Low voltage is a common problem which is aggravated during the air conditioning season by increased current (load) demands and the possibility of power cutbacks (brownouts) by utility companies. The effect of low voltage varies with different types of loads.

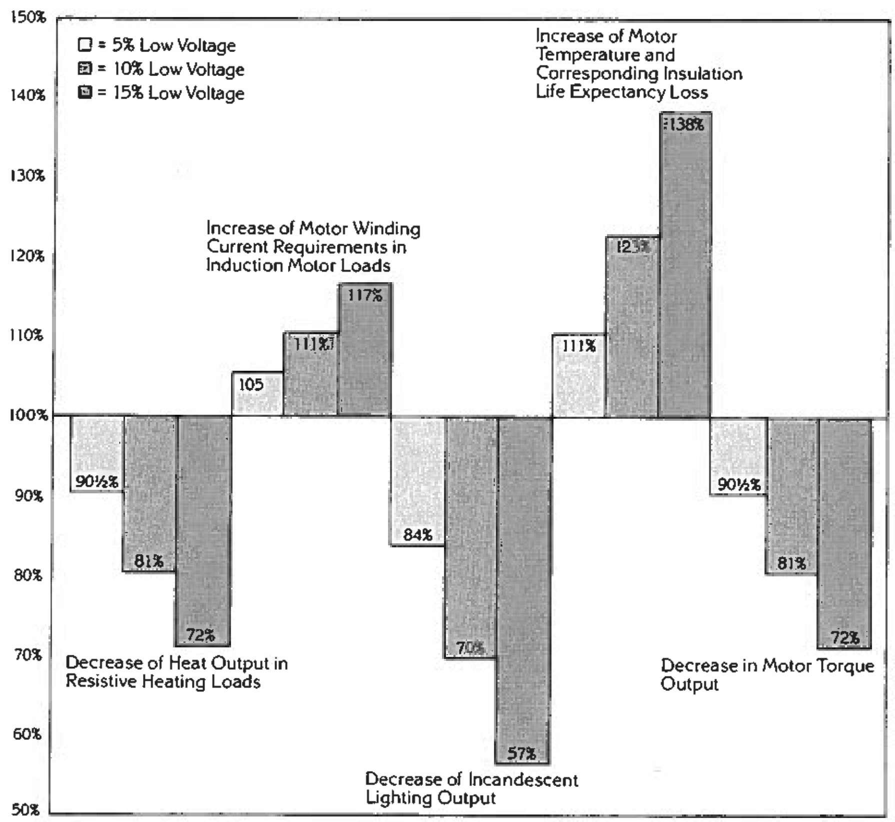


The table below illustrates how low voltage affects different types of loads.

To best compensate for low voltage conditions causing inefficiencies and malfunctions in heating equipment and motors, one of two courses of action may be followed. First, develop a regular maintenance schedule, recording the secondary distribution voltage to determine an average voltage level for the system. Then periodically adjust the primary taps of the power distribution transformers to match as closely as possible the actual average source voltage value. This will minimize the voltage difference between the distribution transformer's secondary voltage and that required by the loads.

When it is impractical to adjust the taps due to intolerable downtime or similar situations, the buck-boost transformer is an excellent alternative. This efficient but inexpensive transformer is capable of bucking (lowering) or boosting (raising) the supply line voltage from ±5% to ±20%.

How Low Voltage Affects Various Equipment Operations and Functions



Acme Transformer manufactures buck-boost units in sizes from 50 VA to 10 KVA. These units are field connected as auto transformers for boosting or bucking existing voltages. This results in a relatively small size transformer developing the capacity to handle loads as high as 363 KVA.

If you would like a FREE Buck-Boost Handbook and Slide Chart Selector, send us a note on your letterhead.

For information on Acme's complete line of FIVE-YEAR WARRANTED dry-type transformers, circle the reader service number and receive your FREE 1979 Master Catalog. Among other things, it answers questions to 42 basic questions about transformers. Or contact your local Acme distributor.

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Interchange

no. 3 in a series

solutions to common transformer problems

Q. As an electrical contractor, I was recently hired to install a transformer in the new addition of a local industry. After connecting the transformer, I tested it with no power applied and found no grounds and all connections properly made. When I turned the transformer on, the primary circuit breaker tripped. Thinking I may have miswired it, I re-examined my connections and had them checked by another electrician, but found no errors. We turned the breaker on again, and it did not trip. What caused the breaker to trip the first time?

A. At first it may have seemed there was an intermittent fault in the transformer, but this seldom occurs. From your description, it appears you experienced nuisance breaker tripping due to **transformer inrush current.**

Figure 1 **Transformer Inrush Current**

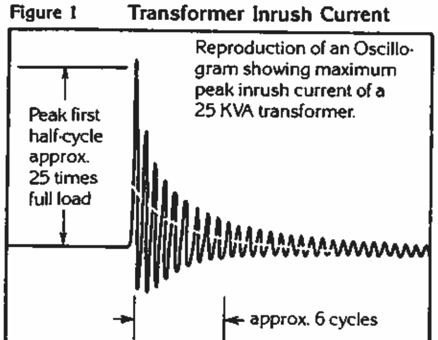
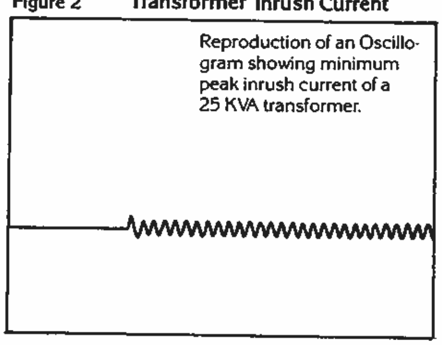
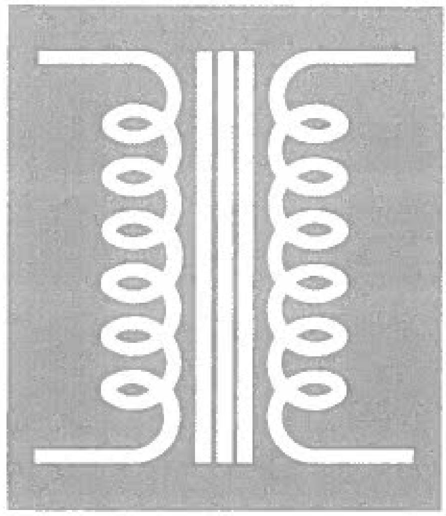


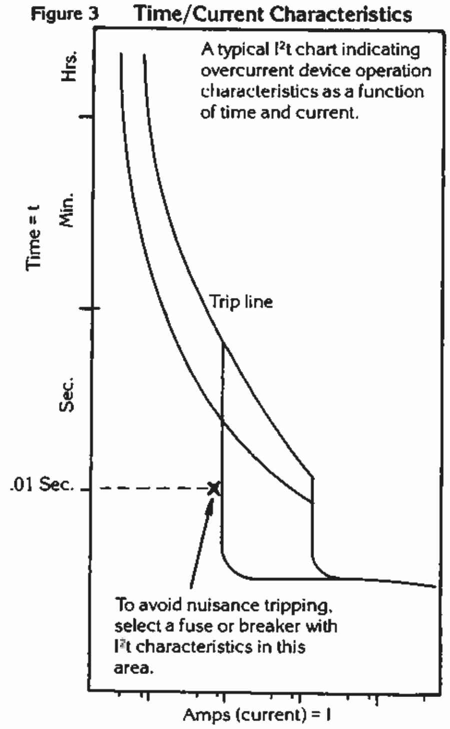
Figure 2 **Transformer Inrush Current**





Characteristics of alternating current cause transformer inrush current. During each half-cycle of flow, alternating current changes into magnetism and is stored in the transformer's iron core (laminations). The stored (residual) magnetism and the magnetism generated at the instant of turn-on are sometimes out of phase. At this point the core is highly saturated and the inrush current is at its highest (approx. 25 times normal primary full load current).

Figure 3 **Time/Current Characteristics**



Inrush current peaks in the first half-cycle of turn-on, and deteriorates to normal current after approximately six cycles (about 1/10 of a second). See Figure 1.

Because it is approx. 25 times normal full load primary current even without a load on the transformer, peak inrush current will often cause some types of overcurrent protection devices to trip or blow.

Should the transformer be turned on at the same point of the cycle at which it was turned off (putting the residual and newly generated magnetism in phase), inrush current would be negligible, and the breaker will stay closed. See Figure 2. Therefore, it is the point of an electrical cycle at which a transformer is turned on that determines the amount of inrush current. This explains why your breaker tripped the first time but not the second.

To prevent transformer overcurrent protection devices from being falsely activated, peak inrush current characteristics should be coordinated with I^2t charts applying to various types of fuses and circuit breakers. See Figure 3.

Here is a general rule for establishing the overcurrent protection rating necessary to prevent nuisance tripping:

> Multiply transformer full load amps by 25. This peak current valve will last about .01 seconds. Utilizing an I^2t chart, locate the device with a rating that will not "trip" or "blow" below these values. (See Figure 3).

I^2t charts are available from fuse or circuit breaker manufacturers through most electrical distributors.

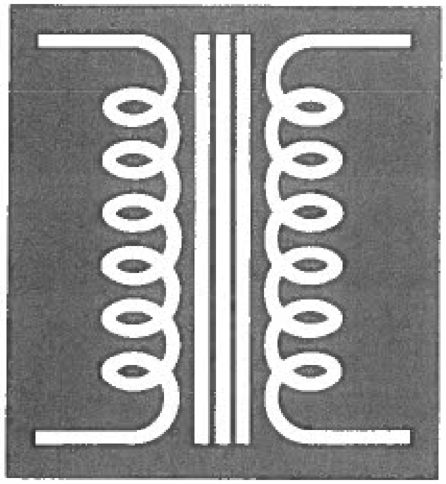
Interchange

no. 4 in a series

solutions to common transformer problems

Q. I have a dry-type transformer installation coming up, and the building engineer is really concerned with proper overcurrent protection. Several single and three-phase units are required, ranging in size from 1/4 KVA to 225 KVA. They will be used to change 480V down to 120V and 240V single phase, two wires; 240/120V single phase, three wires; and 208Y/120V three phase, four wires. Is there an easy way to determine the proper overcurrent protection required on an installation of this type?

A. YES, THERE IS AN EASY WAY! The 1978 National Electrical Code covers overcurrent protection in Articles 450-3(b) and 240-3. A tabular



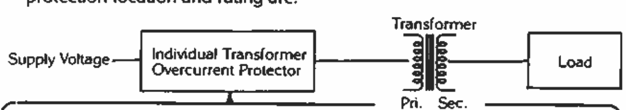
presentation of these two Code Articles is illustrated in Tables 1 and 2 below. This information should enable you to determine the proper overcurrent protection ratings and locations (primary or secondary or both) for any installation of this type.

To eliminate the calculations and provide you with a ready reference, Acme Transformer has prepared tables for various KVA rated, single and three-phase transformers showing: (1) standard input voltages from 120 to 600 volts; (2) the rated (full load) currents for standard KVA sizes; (3) the appropriate maximum amps rating of the overcurrent protection device to be used with each transformer; (4) reproduction of Tables 1 and 2 below; and (5) Section 240-6 of the Code showing standard ampere ratings for fuses and breakers. For your FREE copy, circle the reader service number or contact your local Acme distributor.

For information on Acme's complete line of FIVE-YEAR WARRANTED dry-type transformers, write for the 1979 Master Catalog. Among other things, it provides answers to 42 basic questions about transformers.
Do you have a transformer-related problem? Write or call us, and we'll be happy to answer your questions. We're at (716) 968-2400.

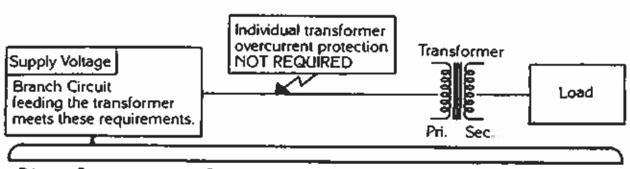
HOW TO OVERCURRENT PROTECT 600 VOLT CLASS TRANSFORMERS AND ASSOCIATED WIRING in accordance with the '78 National Electrical Code (Articles 450-3 and 240-3)

I. If the transformer is single phase and the secondary has ONLY two wires, **primary protection ONLY is required.** The overcurrent protection location and rating are:



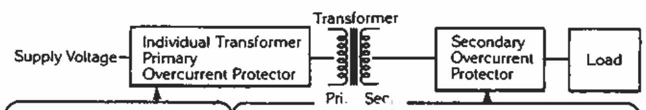
Primary Current	Overcurrent Protection Rating
9 amps. or more	125% of rated primary current (or next higher standard rating)
2 to 9 amps.	167% max.
less than 2 amps.	300% max.

IA. If the branch circuit feeding the transformer has overcurrent protection which meets the individual protector requirements in I. above, then individual transformer protection is NOT required.



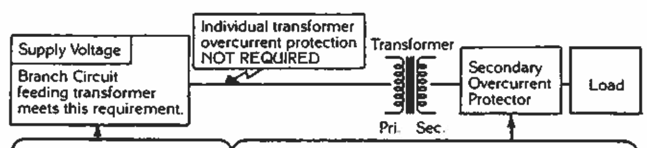
Primary Current	Overcurrent Protection Rating
9 amps. or more	125% of rated primary current (or next higher standard rating)
2 to 9 amps.	167% max.
less than 2 amps.	300% max.

II. If the transformer has more than 2 wires on the secondary and is single or three phase, **primary and secondary protection are required.*** The overcurrent protection locations and ratings are:



Overcurrent Protection Rating	Secondary Current	Overcurrent Protection Rating
Not more than 2½ times (250%) primary current	9 amps. or more	125% (or next higher standard rating)
	less than 9 amps.	167% max.

IIA. If the branch circuit feeding the transformer has overcurrent protection which meets the individual primary overcurrent protector requirements in II above, then individual primary protection is NOT required. Secondary protection IS required.



Overcurrent Protection Rating	Secondary Current	Overcurrent Protection Rating
Not more than 2½ times (250%) primary current	9 amps. or more	125% (or next higher standard rating)
	less than 9 amps.	167% max.

SECTION 240-6 OF THE 1978 NATIONAL ELECTRICAL CODE
The standard ampere ratings for fuses and inverse time circuit breakers shall be considered 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000.
Exception: Additional standard ratings for fuses shall be considered 1, 3, 6, 10, and 601.
"Extracted by permission from NFPA 70-1978, National Electrical Code®, Copyright© 1977, National Fire Protection Association, Boston, MA."

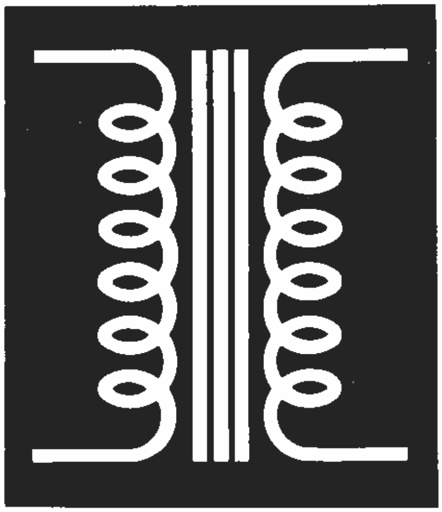
* In cases where the secondary is overcurrent protected, the primary overcurrent protection rating can be no more than 250% (2½ times) full load amps (shown on above charts).
Example: If a 10 KVA, single phase transformer has a 480V primary and a 120/240V secondary, and the secondary is overcurrent protected, maximum primary overcurrent protection rating is 20.8 amps (full load current) x 2½ (250%) = 52. Therefore, use a standard 50 amp fuse or breaker selected from NEC Section 240-6 (above).

Interchange

no. 5 in a series

solutions to common transformer problems

Q. I recently installed a 37½ KVA, single phase, dry-type transformer with a 240 volt, two-wire output. After connecting it, I used a voltmeter to measure voltage from each secondary terminal to ground. I was surprised to read 60 volts on one, and almost 180 volts on the other. With other installations I always read 120 volts from either secondary terminal to ground. I then turned off power to the unit, and used a 500 volt Megger to measure insulation resistance of the 240 volt secondary to ground. This read over 10,000 "megs," almost infinity. Does this mean there was an intermittent ground in the secondary?



A. All of your findings are well within acceptable values. The voltage you are measuring is due to the capacitance effect between the transformer's secondary winding and enclosure ground (Figure 1). Voltage readings of 60 and 180 volts between an ungrounded 240 volt output and ground are common when a sensitive voltmeter (20,000 ohms per volt or greater) is used, even though the transformer secondary is totally isolated from ground.

With less sensitive meters (1,000 ohms per volt), a reduced reading of 20 to 40 volts would be common. This occurs because the capacitance voltage is "loaded down" by the less sensitive metering.

This difference in meter indications leads us to a method of detecting if a fault actually exists, or if the voltage indication is due to capacitance effects. Connect a 25 watt or larger light bulb from the winding to ground and measure the voltage across the bulb (make certain the bulb is rated for 240 volts). If the bulb fails to glow and no voltage is measured across it, then the previous voltage measurement is caused by capacitance of the transformer windings to ground. If the bulb glows slightly or if a voltage is measured across the bulb, then there is a fault in the transformer. Likewise, the Megger would read substantially zero. This indication is a very rare occurrence.

Transformer windings are often so well insulated they act as capacitor plates. Such windings can possibly retain a charge long after they have been de-energized. Whenever a transformer enclosure is opened, particularly on a unit greater than 600 volts, it is a good idea to tie the windings to ground before anyone starts work on it.

An explanation of your readings of 120 volts to ground on previous installations is illustrated in Figure 2.

Dry-type transformers are normally manufactured and shipped without the secondary grounded because certain installations require an ungrounded secondary. (For specific conditions requiring secondary grounding, refer to Article 250-5 of the 1978 National Electrical Code). For this reason, secondary grounding is done at the time of installation.

Figure 1

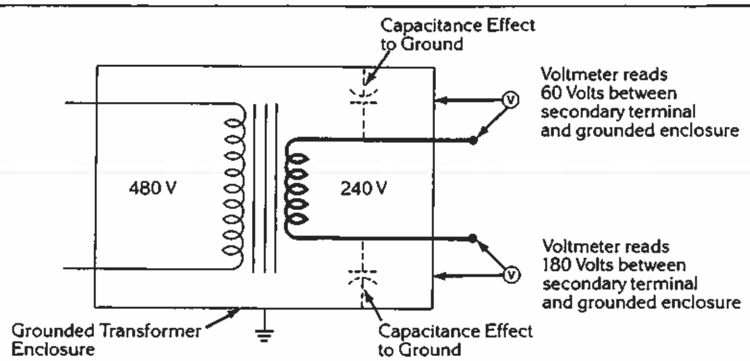
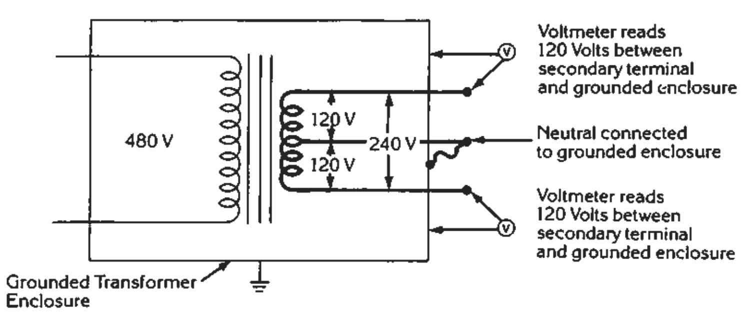


Figure 2

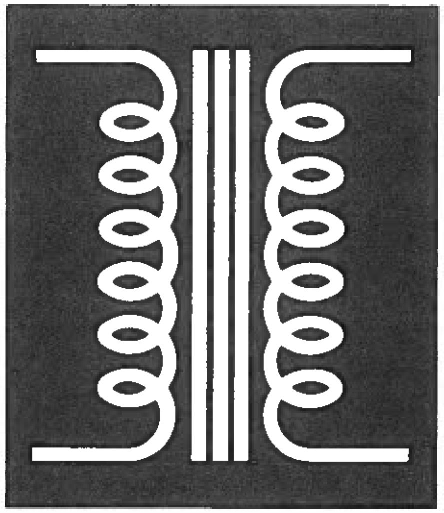


Interchange

no. 6 in a series

solutions to common transformer problems

Q. I recently had a transformer application which required stepping up the voltage from 208 to 230 volts to operate a 5 H.P., single phase air conditioner. My distributor recommended a 1 KVA buck-boost transformer (120 x 240 volt primary, 12/24 volt secondary) for the job. Common sense tells me this can't be right. How can a 1 KVA unit operate a 5 H.P. motor that obviously requires several KVA of transformer capacity?



A. Your distributor was correct. Buck-boost transformers are designed and shipped as isolating transformers with a dual high voltage primary and a dual low voltage secondary (Figure 1). In your application, for a boost of only 22 volts, the buck-boost unit would be field connected as an auto transformer (allowable under Article 210-9, Exception 2 of the 1978 National Electrical Code). To do this, the transformer primary and secondary windings are wired in series (Figure 2).

By applying 208 volts to the input, you obtain 230 volts output. This new auto booster connection results in a 1 KVA transformer having 9.58 KVA capacity. An explanation follows:

The secondary winding for a buck-boost transformer (when auto connected) is the only winding providing a voltage and current transformation. Therefore, it is the limiting factor. Maximum full load current which can flow in the secondary winding is:

$$\text{Maximum Secondary Winding Amps} = \frac{\text{Nameplate KVA} \times 1000}{\text{Secondary Volts}}$$

From your application, then:

$$\text{Maximum Secondary Winding Amps} = \frac{1\ \text{KVA} \times 1000 = 41.67}{24\ \text{Volts}}$$

The 208-to-230 volt transformation is a boosting application in which 22 volts are added to the primary voltage to produce the 230 volt output. Since an auto transformer's KVA rating is based on output volts and amps, the KVA for your connection is:

$$\text{KVA} = \frac{\text{Output Volts} \times \text{Max. Sec. Amps}}{1000}$$

$$\text{KVA} = \frac{230\text{V} \times 41.67\text{A}}{1000} = 9.58$$

The transformer size required to operate a 5 H.P. motor rated 230V at 28 amps (typical for a 5 H.P. motor) is calculated as follows:

$$\text{KVA} = \frac{\text{Volts} \times \text{Amps}}{1000}$$

$$\text{KVA} = \frac{230 \times 28}{1000}$$

$$\text{KVA} = 6.44$$

Since the motor will likely start more than once per hour, it is recommended to have 20% extra transformer capacity to handle starting current which is five to seven times the nameplate running current.

Minimum Transformer KVA = 6.44 KVA + 20% = 7.73

With the KVA required for your installation being 7.73, this unit will adequately serve the purpose.

Buck-boost transformers are supplied as four-winding isolating units. This construction allows them to be connected at least eight different ways as auto transformers and four additional ways as isolating transformers. A single "off-the-shelf" unit can therefore provide a multitude of voltage and KVA combinations.

Figure 1

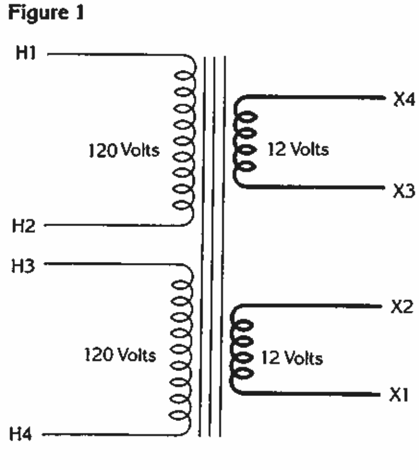
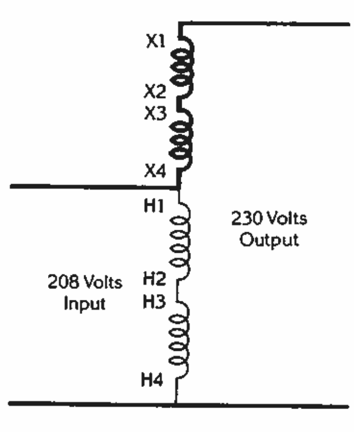


Figure 2



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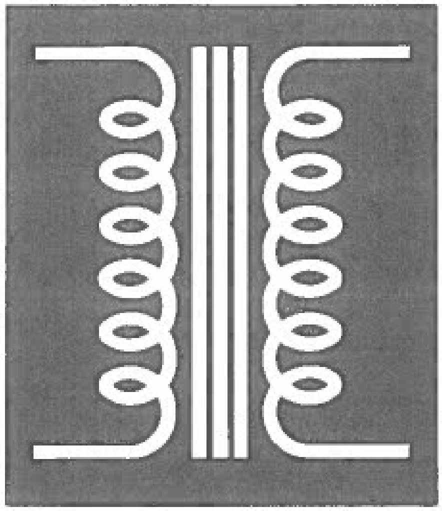
Interchange

no. 7 in a series

solutions to common transformer problems

Q. **I am chief electrician in a large metal-fabricating plant. We use a variety of machines, both foreign and domestic manufacture, and therefore have several different machine-voltage requirements. Our plant secondary distribution system is 480 volts 3Ø, 3 wire ungrounded. Voltage requirements for the various machines include 208Y/120 volts, 240 volts, 380 volts and 600 volts. The largest machine is rated for 75 KVA. I do inventory transformers, but I would like to keep my stock as small as possible. How do I satisfy my voltage needs and minimize the number of transformers I inventory?**

A. Your question is typical of those asked by people involved with voltage-changing requirements. All the voltages you mentioned can be developed from standard single phase, 60 Hz

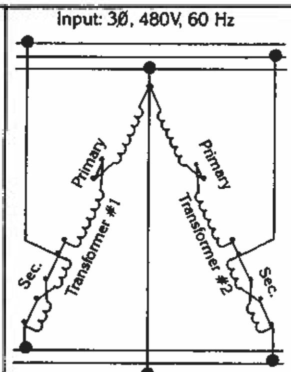


transformers rated 240X480 primary and 120/240 volt secondary. This is accomplished by rearranging the winding connections at the time of usage, producing a variety of possible voltage configurations.

The Table below provides elementary connection diagrams illustrating the output voltage flexibility of several single-phase transformers. The standard 25 KVA, single phase, four-winding transformer (240X480 volt primary — 120/240 volt secondary) would satisfy all output voltage requirements for your particular applications.*

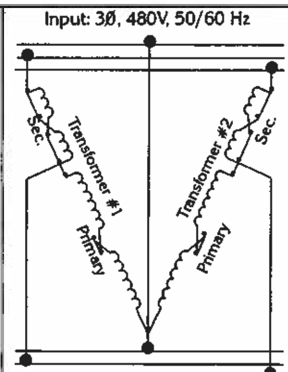
Connection Diagrams and Capacity Charts for Developing 3Ø Voltages from 1Ø Transformers

Input: 3Ø, 480V, 60 Hz



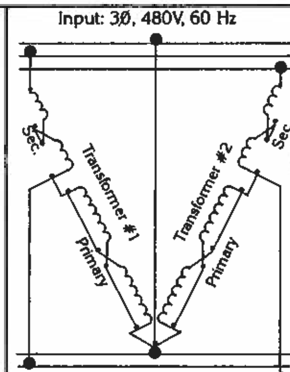
Output: 3Ø, 600V, 60 Hz
Open Delta Auto Connection

Input: 3Ø, 480V, 50/60 Hz



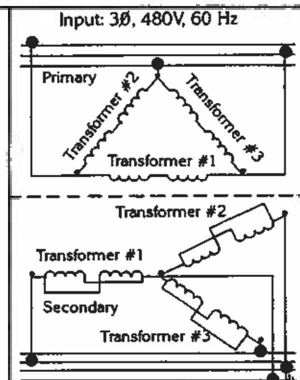
Output: 3Ø, 380V, 50/60 Hz
Open Delta Auto Connection

Input: 3Ø, 480V, 60 Hz



Output: 3Ø, 240V, 60 Hz
Open Delta Auto Connection

Input: 3Ø, 480V, 60 Hz



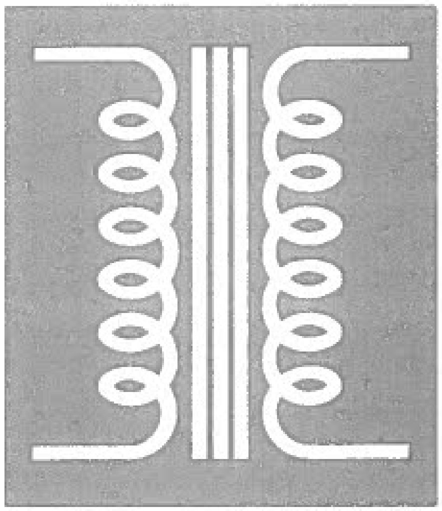
Output: 3Ø, 208Y/120V, 60 Hz
Delta-Wye Insulating Connection

Nameplate KVA Rating of each Standard 1Ø Transformer Used (240 x 480V primary, 120/240V secondary)	Open Delta Auto Connection, 600V — 2 transformers used	Open Delta Auto Connection, 380V — 2 transformers used	Open Delta Auto Connection, 240V — 2 tranformers used	Delta-Wye Insulating Connection, 208Y/120V — 3 transformers used
1	total 3Ø capacity: 8 KVA	total 3Ø capacity: 6.5 KVA	total 3Ø capacity: 3 KVA	total 3Ø capacity: 3 KVA
1½	total 3Ø capacity: 12 KVA	total 3Ø capacity: 9.5 KVA	total 3Ø capacity: 5 KVA	total 3Ø capacity: 4½ KVA
2	total 3Ø capacity: 17 KVA	total 3Ø capacity: 13.5 KVA	total 3Ø capacity: 6 KVA	total 3Ø capacity: 6 KVA
3	total 3Ø capacity: 25 KVA	total 3Ø capacity: 20 KVA	total 3Ø capacity: 10 KVA	total 3Ø capacity: 9 KVA
5	total 3Ø capacity: 43 KVA	total 3Ø capacity: 34 KVA	total 3Ø capacity: 17 KVA	total 3Ø capacity: 15 KVA
7½	total 3Ø capacity: 64 KVA	total 3Ø capacity: 51 KVA	total 3Ø capacity: 26 KVA	total 3Ø capacity: 22½ KVA
10	total 3Ø capacity: 86 KVA	total 3Ø capacity: 68 KVA	total 3Ø capacity: 34 KVA	total 3Ø capacity: 30 KVA
15	total 3Ø capacity: 129 KVA	total 3Ø capacity: 103 KVA	total 3Ø capacity: 52 KVA	total 3Ø capacity: 45 KVA
* 25	total 3Ø capacity: 216 KVA	total 3Ø capacity: 172 KVA	total 3Ø capacity: 86 KVA	total 3Ø capacity: 75 KVA
37½	total 3Ø capacity: 324 KVA	total 3Ø capacity: 259 KVA	total 3Ø capacity: 130 KVA	total 3Ø capacity: 112½ KVA
50	total 3Ø capacity: 433 KVA	total 3Ø capacity: 346 KVA	total 3Ø capacity: 173 KVA	total 3Ø capacity: 150 KVA
75	total 3Ø capacity: 648 KVA	total 3Ø capacity: 518 KVA	total 3Ø capacity: 259 KVA	total 3Ø capacity: 225 KVA
100	total 3Ø capacity: 866 KVA	total 3Ø capacity: 692 KVA	total 3Ø capacity: 346 KVA	total 3Ø capacity: 300 KVA
167	total 3Ø capacity: 1440 KVA	total 3Ø capacity: 1152 KVA	total 3Ø capacity: 588 KVA	total 3Ø capacity: 500 KVA

Interchange

no. 8 in a series

solutions to common transformer problems



Q. During the last twelve months, I installed several dry-type distribution transformers on a project. They were all 10 KVA, 1Ø units with a 240 x 480 volt primary and a 120/240 volt secondary (connected for a three wire, neutral grounded system). The maintenance electrician called me because one of the transformers runs noticeably hotter than the others. A 3 KVA single phase 120V and a 6 KVA single phase 120V load are connected to this transformer as shown on the attached diagram (see Figure 1). When I checked the primary current, it showed the transformer was only 90% loaded. Do you have any idea why this particular unit is overheating?

Figure 1

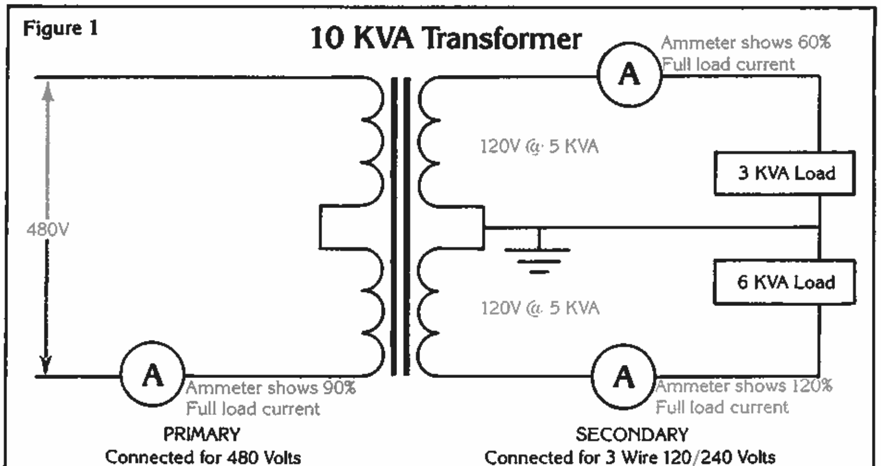
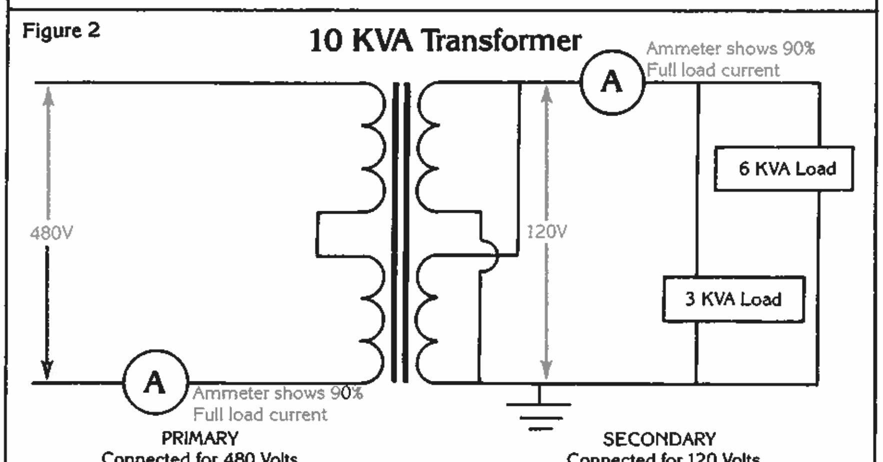


Figure 2



A. Transformer overheating is primarily caused by excessive loading; however, improper primary voltage and frequency can cause similar effects. In your case, a second look at the connection diagram indicates you're overloading one secondary winding with the 6 KVA load. When these loads are connected as illustrated in Figure 1, overloading is present on a portion of the transformer. The transformer used has two separate secondary windings: each is rated for one-half the total transformer KVA at 120 volts. (In your example, each is rated for 5 KVA.) So, even though one load (3 KVA) is less than the maximum available for its seconday winding, the other load (6 KVA) exceeds its secondary's current rating by 20%. This condition causes overheating.

The most important thing to remember when determining actual load current is: ALWAYS measure the secondary current, NOT the primary current alone. The load kilovolt-amperes (KVA) is calibrated by multiplying the voltage by the current (amps) and dividing by 1000:

$$\text{Single Phase KVA} = \frac{\text{Volts x Amps}}{1000}$$

To correct the problem, eliminate the overloading by connecting the two secondary windings in parallel for 2 wire, 10 KVA at 120 volts (as shown in Figure 2). By so doing, ammeter readings for both the primary and secondary currents are at safe levels (90% of full load current).

Interchange

no. 9 in a series

solutions to common transformer problems

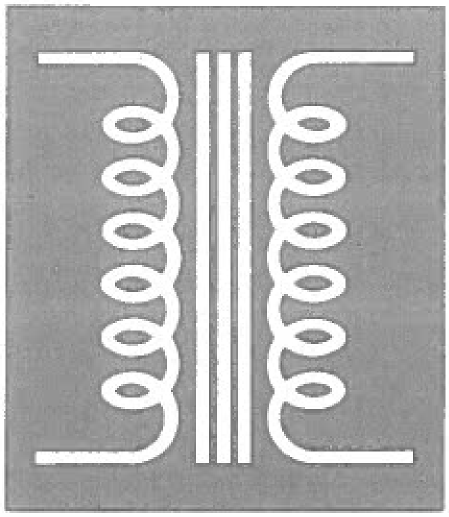
Q. My responsibilities include specifying dry-type distribution transformers and all other electrical equipment for a large factory. I have 480V (3Ø, 4 wire) distributed on the bus system throughout the facility and use many transformers to supply low voltage to machinery and lighting loads.

Lately, I have seen several advertisements and catalogs promoting the use of what are described as "energy efficient" or "low-temperature rise" transformers. Can you explain what "low-temperature rise" transformers are, and tell me if they are really energy efficient?

A. Until recently, the generally accepted practice was for engineers to design and purchasers to specify transformers with a maximum temperature rise of 150°C by resistance—NEMA's and UL's maximum allowable temperature rise with a 220°C insulation system. Further, such transformers were the most economical, considering transformer purchase price and operating expense with low cost power.

But with today's high energy costs and projections for even higher costs in the future, transformer efficiency is a matter of growing economic importance. That's because transformer efficiency directly translates into cost savings for the user.

Low-temperature rise transformers (80°C and 115°C with 220°C insulation) are designed to prevent internal temperatures from rising to the temperature limits



of the insulation system, when the transformers are operated at rated KVA values. This design objective is achieved by reducing internal losses (heat) developed when a load is connected to a transformer.

In order to reduce those losses, the circular mil area of the coil conductors is increased in 80°C and 115°C rise transformers. Larger-area conductor wire offers less resistance; less resistance in the coil means less heat is generated—and lost. (See Figure 1) The following formula illustrates this:

Watts (heat) = I^2 (amperes) X R (resistance)

Since heat loss is wasted energy, the reduction of heat loss by use of larger area conductors results in more efficient transformers. That's what "energy efficient" transformers are all about.

All of the following transformer types incorporate a UL-recognized 220°C insulation system, but have different efficiency and overload characteristics.

The 115°C rise transformer has 20% less heat loss than a 150°C rise transformer, and can carry a 15% continuous overload. Similarly, an 80°C rise transformer has 35% less heat loss than one with 150°C rise, and can carry a 30% continuous overload. There is no overload capability with 150°C rise units.

Because low-temperature rise transformers are built with larger conductors, they cost more than 150°C rise transformers. But, users get their investment back—and then some—through the savings in energy cost over the life of the transformers. The way electricity costs are expected to rise, those savings can only increase in the future.

When specifying low-temperature rise transformers, be sure to include the temperature rise that suits the applications, as well as the 220°C insulation system, to insure increased life expectancy and overload capabilities.

RELATIONSHIP BETWEEN CONDUCTORS' CIRCULAR MIL AREA AND HEAT LOSS
(smaller circular mil area = greater heat loss)

*2 Aluminum Wire with a 70A load	*3 Aluminum Wire with a 70A Load	*4 Aluminum Wire with a 70A Load
P = I^2 X R P = 70^2 X .266† P = 1303.4 Watts	P = I^2 X R P = 70^2 X .336† P = 1646.4 Watts	P = I^2 X R P = 70^2 X .424† P = 2077.6 Watts

P = Watts (Heat) Lost I^2 = Load current squared R = D.C. Resistance

*Not the actual wire size †D.C. resistance from Table 8, page 70-587 of the 1978 NEC.

Figure 1

Acme's complete line of energy-efficient Opti-Miser Transformers includes 80°C rise and 115°C rise transformers (single phase, 37.5-167 KVA and three phase, 30-500 KVA). To see what your own savings can be with low-temperature rise transformers, get our Free Opti-Miser Planning Kit. Here's what's in it: (1) an Opti-Miser catalog; (2) specification guide; (3) sample worksheet with operating cost comparisons between 150°C, 115°C and 80°C rise units; (4) blank worksheet for comparison on your specific applications; (5) slide chart for easy and convenient calculation of savings with Opti-Miser units, and (6) price sheet.

To receive your FREE Opti-Miser Planning Kit, circle the reader service number.

For information on Acme's complete line of FIVE-YEAR WARRANTED dry-type transformers, contact your local Acme distributor or send us a note on your letterhead and we'll send you the 1980 General Catalog. Among other things, it provides answers to 42 basic questions about transformers. Do you have a transformer-related problem? Write or call us. We'll gladly answer your questions. We're at 716-968-2400.

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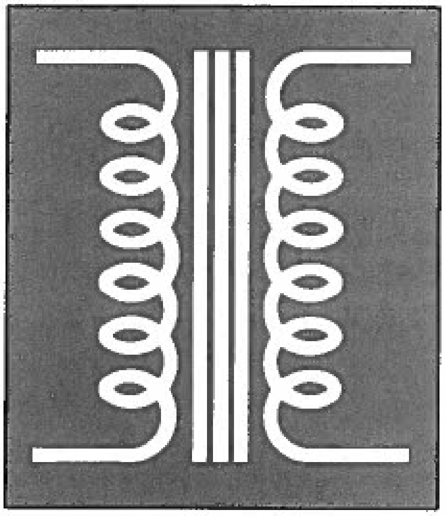
Interchange

no. 10 in a series

solutions to common transformer problems

Q. My next project involves upgrading the electrical service of a small warehouse that has approximately 52 KVA of 240 volt—3Ø load, and 6 KVA of 120 volt—1Ø (2 wire) lighting load utilizing a 480 volt—3Ø source voltage. Is one transformer connection more suitable than any other when banking transformers for such an application?



A. When handling single-phase and three-phase loads in combination as you described, a closed delta circuit is generally used. Typically, this circuit uses three single-phase transformers connected as shown in Figure 1. To power your 3Ø loads, each of these three transformers would be sized at 25 KVA (totalling 75 KVA three phase) while supplying ample reserve capacity. But to carry the additonal requirement of the 1Ø lighting load, one of the transformers would have to be re-sized to 37½ KVA,* creating a "hi-leg" closed delta circuit.

This might seem to be a practical approach to your application, but circulating current within the closed delta—a result of mismatched transformer impedances and/or unbalanced loading—will cause false loading. When that happens, the load will appear to be well within the limit of the combined nameplate ratings, but the load plus the circulating current can cause the transformers to overheat. (Note: Even when equal KVA transformers are used, it is important to match their impedances and voltage ratios. Banking transformers produced by different manufacturers can also result in circulating current problems in a closed delta connection.)

A more satisfactory solution involves the use of only TWO single-phase transformers wired in an open delta configuration. Connected in this manner, the system's three-phase capacity equals the total single-phase transformer KVA ratings multiplied by 86.6%. When applying this to your application, two 37½ KVA units are required to handle the three-phase load, leaving a safety factor for future three-phase load additions or frequent motor starts. With the addition of the single-phase lighting load, the capacity of one transformer needs to be increased to 50 KVA* (see Figure 2), creating a "hi-leg" open delta circuit.

Open delta circuits provide two advantages over closed delta circuits: (1) fewer transformers are required (two with open delta, three with closed delta), and (2) the closed path through which circulating current flows is eliminated.

*This rating is determined by doubling the KVA value of the 1Ø lighting load, then adding it to the KVA rating of the transformer handling that load.

FIGURE 1 Closed Delta "Hi-Leg" Connection

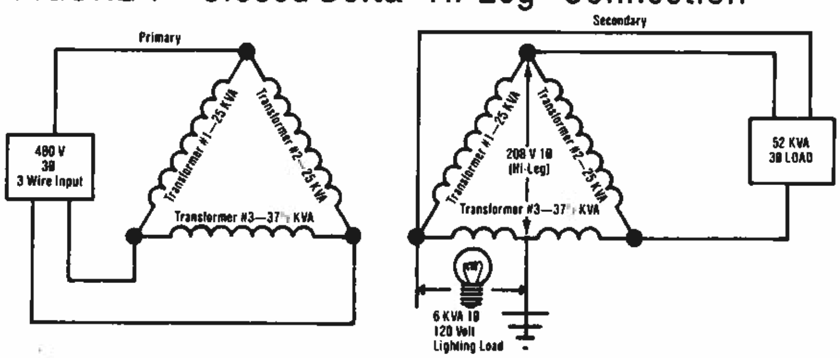
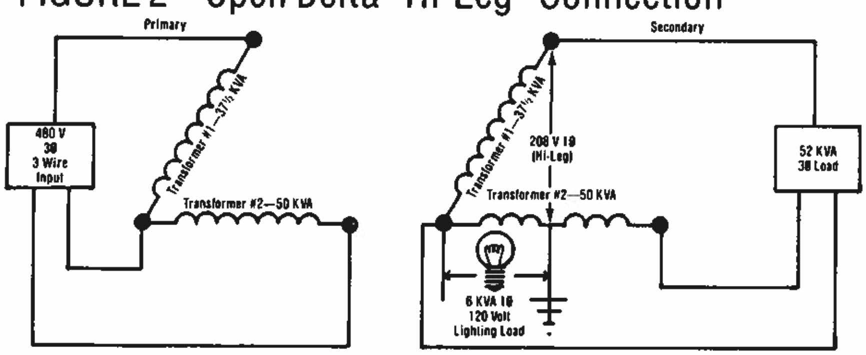


FIGURE 2 Open Delta "Hi-Leg" Connection

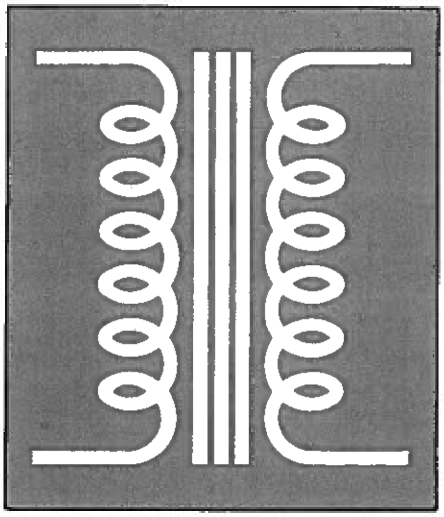


no. 11 in a series

Interchange

solutions to common transformer problems

Q. I have been assigned the task of laying out some process control equipment for a new section of our manufacturing facility. This equipment requires several magnetic contactors to turn the electrical power on and off. My source voltage is 480 volts—3Ø and all the contactors have 120 volt—1Ø coils. Are there special precautions I should take in specifying transformers to operate the contactors?



A. Several types of transformers have voltage ratios to reduce 480 volts to 120 volts, but one type is particularly suited to supply power to electromechanical devices (contactors, relays, solenoids, timers, etc.): industrial control transformers.

And even though your supply voltage is three phase, you will need only a single-phase transformer because the contactor circuit is single phase.

In accordance with NEMA Standard ICS-2-212, contactors must be able to pull in (close) with a minimum 85% of their rated voltage applied. While pulling in, an unusually large amount of current is demanded—often five to ten times that of a closed contactor. This inrush current lasts up to 20 milliseconds—until the contactor closes—then rapidly returns to a normal level known as the sealed or holding current.

Conventional distribution transformers are designed with voltage regulation parameters sufficient to operate lighting and motor loads. However, if conventional distribution transformers are used to supply contactors, high inrush current would cause their voltage levels to drop below the 85% minimum required to pull in the contactors (See Figure 1).

When this happens, the contactors will chatter, but won't close, resulting in equipment malfunction and contactor damage.

Industrial control transformers will accommodate momentary inrush current without sacrificing, beyond practical limits, secondary voltage stability. Typical units incorporate a larger conductor cross section and a larger core than comparable conventional distribution transformers. Because of this designed-in voltage regulation characteristic, industrial control transformers will maintain at least 90% of their output voltage when overloaded five to ten times their nameplate ratings (See Figure 2). This assures that a better-than-minimum voltage is applied to the contactors at all times.

In addition to an excellent degree of voltage regulation, industrial control transformers feature terminal boards, mounting plates and no enclosure for easy installation in control panels. These advantages make the industrial control transformer an ideal choice for your application.

FIGURE 1
Conventional Distribution Transformers

Voltage Regulation Characteristics During Inrush Current

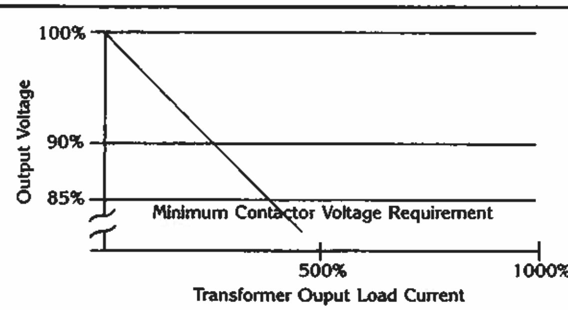
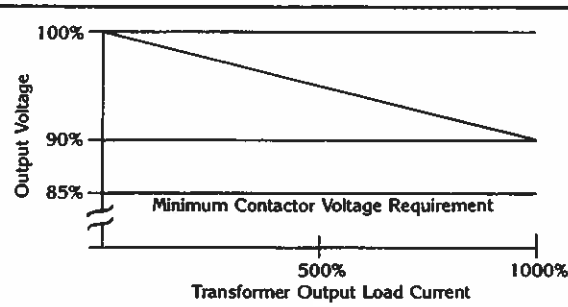


FIGURE 2
Industrial Control Transformers

Voltage Regulation Characteristics During Inrush Current



Acme Transformer's complete line of "off-the-shelf" industrial control transformers features the most units and voltage combinations available in the industry. All are suitable for 50/60 Hz applications, feature sturdy terminal boards, range in size from 50VA-5000VA, are UL-recognized/CSA listed and possess voltage regulation far exceeding NEMA standards.

For more information on these and other FIVE-YEAR-WARRANTED transformers, circle the reader service number or contact your local Acme distributor to receive our 1980 General Catalog. Among other things, it provides answers to 42 basic questions about transformers. Do you have a transformer-related problem? Write or call us. We'll gladly answer your questions. We're at 716-968-2400.

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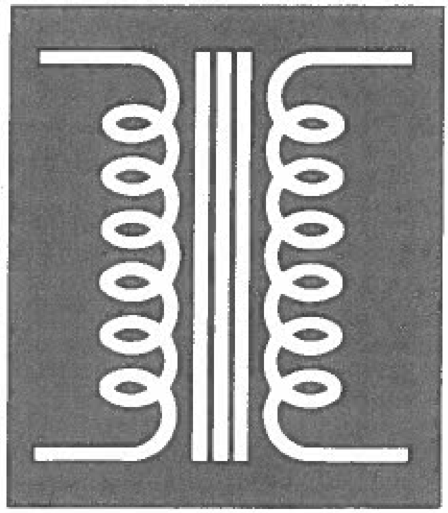
Interchange II

solutions to common transformer problems

Q. I am a plant maintenance engineer in charge of the electrical equipment inside a large manufacturing facility. Several dry-type distribution transformers are used to step down our 480-volt bus duct system to 208Y/120 volt and 240 volt services. Because of constantly changing manufacturing requirements, the load values on these transformers vary from one year to the next. During routine maintenance, I have found some of the transformers to be overloaded. What effect, if any, will these overloads have on our transformers?



A. Overloading a transformer will shorten its life. This is primarily due to more amperes being demanded from the transformer than the wire or foil in its coils is rated to provide. Remember . . . a transformer is composed of only three basic parts:

1. an iron core;
2. a primary and a secondary coil composed of insulated wire or foil;
3. electrical insulation which is used between the primary and secondary coils and between the frame and layers of wire or foil in a coil.

Life expectancy of the iron core and the primary and secondary conducting material is basically unaffected by overload. But overloading **does** generate excessive heat in the coils. This causes the electrical insulation to deteriorate and eventually break down, producing a fault that results in a transformer failure.

Heat generated by current flow (amperes) in a transformer coil is expressed by Ohm's Law: Watts (heat) = Amperes^2 x Resistance. If you consider the winding resistance (resistance of the conducting material in the coil) to be constant and the amperes to be a percentage of full load, the heat generated can be expressed in terms of the (% Load)^2. The percent of full load heat generated within a transformer at various loads is shown in Figure 1. A relatively small percentage of overloading causes a rather significant percentage of heating. For example, a 20% overload causes 44% more heat than full loading.

Constant overloading greatly shortens transformer life, while constant underloading serves to extend the life. This is illustrated in Figure 2.

Figure 1

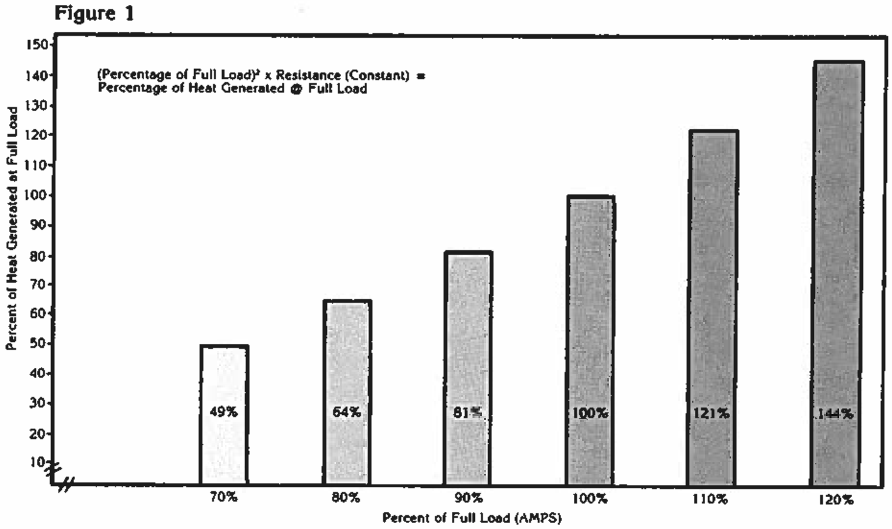
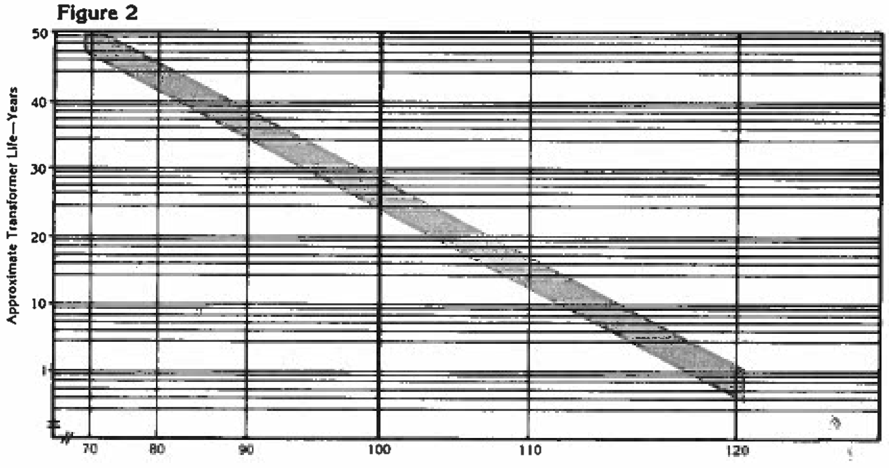


Figure 2



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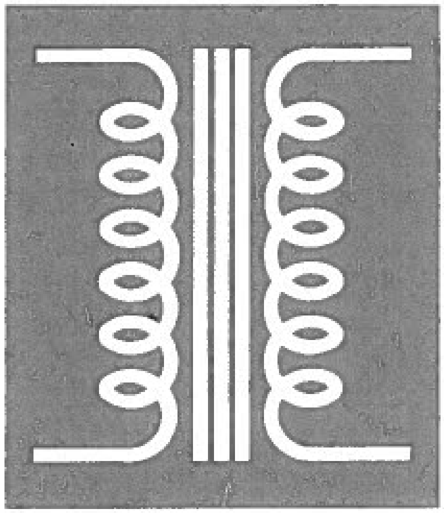
no. 12 in a series

Interchange

solutions to common transformer problems

Q. As a specifier, I am responsible for ensuring that the proper products are supplied to my jobs. Regarding 600V Class, general purpose dry-type transformers, what is the essential information I need to write the specifications?



A. All transformer specifications must include certain basic information, such as KVA levels and voltage requirements. In addition, other parameters should be specified to fit the special demands of the application and/or location (e.g., a metalworking factory or a boiler room). Product quality should also be ensured by requiring third party witness/testing and compliance with industry standards.

Below is a checklist of essential dry-type-transformer specifications. Use these to form the basis for writing your specs.

Acme Transformer's 1980 General Catalog presents a detailed specification guide for the 600 volt class as well as for our other lines FIVE-YEAR-WARRANTED, dry-type transformers. In addition, it provides answers to 42 basic transformer questions. For your FREE copy, circle the reader service number or contact your local Acme distributor.

If you would like free reprints of Interchange ads (#1 through #12), drop a note on your letterhead to our marketing communications manager and we'll send you the complete set in an attractive wrap-around folder.

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Checklist for Dry-Type Transformer Specifications

1. KVA Capacity: ____________
2. Number of Phases: 1Ø ☐; 2Ø ☐; 3Ø ☐
3. Frequency: 50 Hz ☐; 60 Hz ☐; 400 Hz ☐
4. Primary Voltage: ____________
5. Secondary Voltage(s): (A) ______ (B) ______ (C) ______
6. Insulation System and Temperature Rise:

Insulation System	Temperature Rise	Transformer Size
☐ 150°C	80°C	Typically less than 1 KVA
☐ 185°C	115°C	Typically no larger than 25 KVA 1Ø-15 KVA 3Ø
☐ 220°C	150°C	Typically larger than 30 KVA —standard product
☐ 220°C	115°C	Typically larger than 30 KVA —energy efficient
☐ 220°C	80°C	Typically larger than 30 KVA —energy efficient

7. Sound Levels: In accordance with NEMA Standard ST-20-1972 (R-1978)
8. Overload Capability: ☐ Yes ☐ No

   Define ____________

   ____
9. Enclosure: ☐ Indoor ☐ Outdoor ☐ Ventilated ☐ Non-ventilated.
10. Windings: ☐ Aluminum ☐ Copper
11. Terminations:
    - ☐ Up to 25 KVA 1Ø & 15 KVA 3Ø typically Wire Leads
    - ☐ 30 KVA and larger—1Ø & 3Ø typically Bus Bar
    - ☐ Aluminum
    - ☐ Copper

    Note: Specify lugs separately.
12. Primary Taps: In accordance with NEMA Standard ST-20-1972 (R-1978)
13. Mounting: ☐ Wall* ☐ Floor ☐ Trapeze

    *Generally not available for units larger than 75 KVA
14. Type of Load and Duty Cycle: ____________
15. Industry Standards:
    - (A) UL Standard 506, 8th edition (7/22/72);
    - (B) CSA Standard 22.2-47, 1977 and 22.2, 1956 (R-1959);
    - (C) 1978 National Electric Code;
    - (D) National Electrical Manufacturers' Association (NEMA) 51-20-1972 (R-1978);
    - (E) American Standards Institute (ASI)
16. Warranty: At least one year from date of shipment.

no. 2 in a series

Interchange II

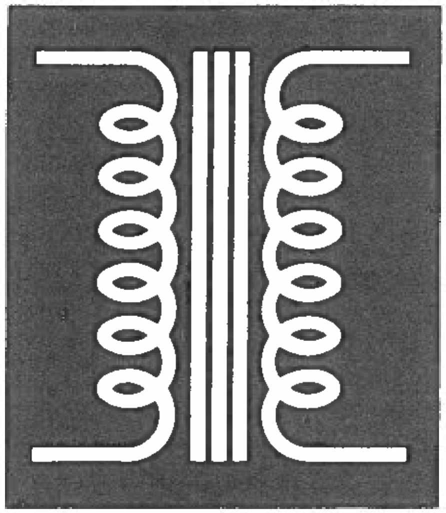
solutions to common transformer problems

Q. As an electrical contractor doing a majority of my work for manufacturing plants, I'm often asked to reduce bus duct voltage of 600V or 480V down to 208V or 120V. The dry-type transformers I install for this purpose range in size from a few KVA to several hundred KVA. Is there a simple method for calculating the amount of short circuit current created when a fault occurs on the secondary of a dry-type transformer?

A. Your concern for the amount of short circuit current that can occur shows good planning. When a fault occurs on or near the secondary (output) of a transformer, the short circuit current is many times greater than full load current.

Article 110-9 of the 1981 National Electrical Code states: "Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the system voltage and the current which is available at the line terminals of the equipment." This means when a fuse, circuit breaker or similar overcurrent protection device is used to protect the transformer, it must be capable of operating under large fault currents.

(Article 450 of the National Electrical Code basically states that the transformer secondary can be over-



current protected for a maximum of only 125% of full load current. This relates to the size (ampere rating) of the fuse or breaker. Article 110-9 deals with the capability of a fuse or breaker to open and clear the fault current.)

The following formula provides a means of conservatively estimating maximum short circuit current created at the transformer's secondary:

$$\text{Maximum Secondary Short Circuit Current} = \frac{\text{Full Load Transformer Secondary Amps}}{\text{Transformer Impedance (\%)}}$$

This formula implies the source of power is very large, and the voltage will not sag during a fault.

Example: Determine the short circuit current at the secondary terminals of a 150 KVA, 3-phase transformer. Secondary voltage is 208Y/120; impedance is 2%.

Before solving the formula for maximum secondary short circuit current, you need to determine full load secondary amps.

$$\text{Full Load Secondary Amps} = \frac{\text{KVA} \times 1000}{1.73 \times \text{Sec. Volts}}$$

$$\text{Full Load Secondary Amps} = \frac{150 \times 1000}{1.73 \times 208}$$

$$\text{Full Load Secondary Amps} = 417$$

With this information, maximum secondary short circuit current can be determined:

$$\text{Maximum Secondary Short Circuit Current} = \frac{417 \text{ (Secondary Amps)}}{2\% \text{ (Transformer Impedance)}}$$

$$\text{Maximum Secondary Short Circuit Current} = 20{,}850 \text{ Amps}$$

In this example, no consideration was given to the impedance of the line supplying power to the transformer. In many instances, this information is not readily available. Therefore, be certain to use the worst case conditions illustrated above.

Figure 1 lists full load currents for single-phase and three-phase transformers at commonly used voltages of 600 volts and below.

To eliminate calculating full load amps and to provide you with a ready reference, Acme Transformer has compiled the information in Figure 1 on a pocket-size card. In addition, we have included full load amps at common voltages for various sizes of single and three-phase motors. For your FREE card, circle the reader service number or contact your local Acme distributor.

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FULL LOAD CURRENT IN AMPERES— SINGLE PHASE CIRCUITS

KVA	120 V	208 V	240 V	277 V	380 V	480 V	600 V
.050	0.4	0.2	0.2	0.2	0.1	0.1	0.1
.100	0.8	0.5	0.4	0.3	0.2	0.2	0.2
.150	1.2	0.7	0.6	0.5	0.4	0.3	0.3
.250	2.0	1.2	1.0	0.9	0.6	0.5	0.4
.500	4.2	2.4	2.1	1.8	1.3	1.0	0.8
.750	6.3	3.6	3.1	2.7	2.0	1.6	1.3
1	8.3	4.8	4.2	3.6	2.6	2.1	1.7
1½	12.5	7.2	6.2	5.4	3.9	3.1	2.5
2	16.7	9.6	8.3	7.2	5.2	4.2	3.3
3	25	14.4	12.5	10.8	7.9	6.2	5.0
5	41	24.0	20.8	18.0	13.1	10.4	8.3
7½	62	36	31	27	19.7	15.6	12.5
10	83	48	41	36	26	20.8	16.7
15	125	72	62	54	39	31	25
25	208	120	104	90	65	52	41
37½	312	180	156	135	98	78	62
50	416	240	208	180	131	104	83
75	625	360	312	270	197	156	125
100	833	480	416	361	263	208	166
167	1391	802	695	602	439	347	278
250	2083	1201	1041	902	657	520	416

FULL LOAD CURRENT IN AMPERES— THREE PHASE CIRCUITS

KVA	208 V	240 V	480 V	600 V
3	8.3	7.2	3.6	2.9
4	12.5	10.8	5.4	4.3
6	16.6	14.4	7.2	5.8
9	25	21.6	10.8	8.6
15	41	36	18.0	14.4
22	62	54	27	21.6
30	83	72	36	28
45	124	108	54	43
75	208	180	90	72
112	312	270	135	108
150	416	360	180	144
225	624	541	270	216
300	832	721	360	288
500	1387	1202	601	481
750	2084	1806	903	723

$$\text{Maximum Short Circuit Current} = \frac{\text{Full Load Current}}{\text{Transformer Impedance (\%)}}$$

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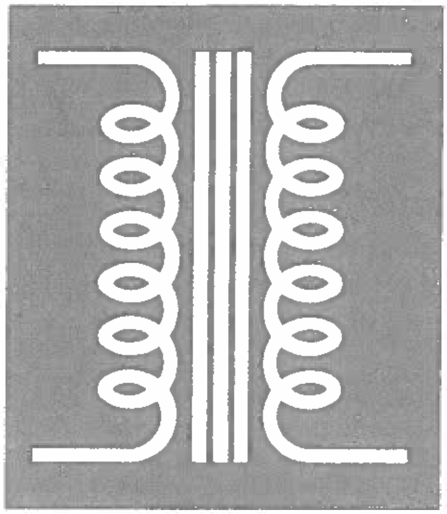
Interchange II

solutions to common transformer problems

Q. As a plant electrical engineer, one of my functions is laying out control panels. These panels typically contain up to eight contactors used to control 480V power for process heating. The contactor holding coils all operate on 120V, and must open and close load currents of 5 amps to 200 amps. Is there a simple method for determining the type and size of transformer needed to reduce 480V to 120V for operating contactor coils?

A. There are two basic types of transformers available which will change 480V to 120V. One type (distribution) is intended for use in power work such as lighting, operating calculators, hand tools and similar equipment. The other (industrial control) is intended for operating contactors, starters, and similar types of loads. The principal difference in the two lies in the output regulation of the transformer at various loads.

Distribution transformers have good voltage regulation, provided they are not overloaded. Industrial control transformers are designed for very good regulation even when momentarily overloaded to several times their nameplate rating. (INTERCHANGE #11 gives an in-depth discussion of regulation.) Regulation is usually expressed as the percentage difference between no load voltage and the voltage available when a given load is applied to a transformer's output winding(s).



Your specifications call for contactors to operate loads of 5 amps to 200 amps. According to NEMA designations, which apply to the maximum ampere rating of power contactors, you will need contactor sizes 00 through 5: 00 is rated for 9 amps, 5 is rated for 270 amps.

When contactor coils are first energized, a large current is required. This is known as inrush and is expressed as inrush VA (volt-ampere). The duration of this requirement is less than 1 second. When the contactor is closed, the volt ampere demand diminishes greatly. This steady-state requirement is known as sealed VA. CAUTION: There is wide variation among manufacturers in inrush VA and sealed VA requirements for the same NEMA size contactor.

It is good practice to size transformers so the voltage will be at least 90% of the current value during inrush.

Here's an example of how to size a transformer for operating a **Size 2** Allen-Bradley 700 Series contactor:

1. Refer to Figure 1. From this figure, you know that 240 VA inrush and 31 VA sealed are required.
2. Go to Figure 2. Under the 90% secondary voltage column, locate the number equal to or greater than your required 240 VA. The first listing is 240 VA.
3. Move left to the column titled **Nameplate Rating.** This is 50 VA continuous which satisfies the 31 VA requirement of the contactor.

Always select a transformer with an inrush VA capacity and continuous (sealed) VA equal to or greater than that required by the contactor. Don't neglect the current requirements of indicating lights, displays, and timing devices. These don't have an inrush VA but are energized at the same time as other circuit components. Their total VA should be added to the total inrush VA. An under-sized transformer can result in the contactor chattering and failing to close, and overheating of the transformer.

Acme Transformer's complete line of "off-the-shelf" industrial control transformers features the most units and voltage combinations available in the industry. All are suitable for 50/60 Hz applications, feature sturdy terminal boards, range in size from 50VA-5000VA, are UL-recognized/CSA listed and possess voltage regulation far exceeding NEMA standards.

For more information on these and other FIVE-YEAR-WARRANTED transformers, circle the reader service number or contact your local Acme distributor to receive our General Catalog. Among other things, it provides answers to 42 basic questions about transformers.

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TYPICAL MAGNETIC MOTOR STARTER & CONTACTOR DATA
60 Hz, 120 Volt, 3-Pole

CONTACTOR MANUFACTURER	N.E.M.A. SIZE 00	0	1	2	3	4	5	
500 SERIES ALLEN BRADLEY		192	192	240	660	1225		VA Inrush
		29	29	29	45	69		VA Sealed
700 SERIES	53	110	175	240	580	1000	1945	VA Inrush
	15	20	22	31	43	65	98	VA Sealed
ASEA			75	230	400	900	1600	VA Inrush
			10	30	45	55	100	VA Sealed
CROUSE-HINDS (ARROW HART DIV.)	175	175	175	175	680	680	5500	VA Inrush
	21	21	21	21	45	45	240	VA Sealed
CUTLER-HAMMER (CITATION LINE)	87	104	104	394	1034	1034	1034	VA Inrush
	15	20	20	51	100	100	100	VA Sealed
FURNAS	218	218	218	218	440	957	1518	VA Inrush
	25	25	25	25	45	75	116	VA Sealed
GENERAL ELECTRIC	144	144	144	528	1152	1248	3600	VA Inrush
	24	24	24	60	83	86	276	VA Sealed
GTE-SYLVANIA	75	120	200	550	1140	1380	2700	VA Inrush
	20	30	35	80	120	145	370	VA Sealed
ITE GOULD		198	198	360	790	1400	900	VA Inrush
		24	24	41	57	70	10	VA Sealed
SQUARE D	118	245	245	311	700	1185	2970	VA Inrush
	11	27	27	37	46	85	212	VA Sealed
WESTINGHOUSE	160	160	160	160	625	625		VA Inrush
	25	25	25	25	50	50		VA Sealed

FIGURE 1

REGULATION DATA CHART
FOR
INDUSTRIAL CONTROL TRANSFORMERS

Continuous Nominal VA (NAMEPLATE RATING)	Inrush VA at 20% PF 95% Sec. Voltage	90% Sec. Voltage	85% Sec. Voltage
50	200	240	280
75	350	470	580
100	400	575	770
150	800	950	1250
250	1500	2200	2750
300	2000	2800	3900
350	3200	3700	4900
500	4200	5800	8000
750	8000	11000	15000
1000	13000	18000	23000
1500	15000	24000	31000
2000	20000	32000	41000
3000	39000	60000	77000
5000	75000	120000	150000

NEMA standards require all magnetic devices to operate successfully at 85% of rated voltage. The 90% Secondary voltage column is most commonly used for transformer selection.

FIGURE 2

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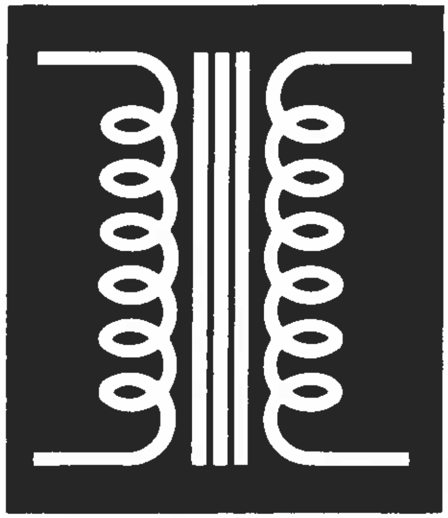
Q. I am responsible for the electrical facilities of a large company with plants across the country. The incoming power voltages to these plants include:
a. 208Y/120—4 wire, 3-phase;
b. 240—3 wire, 3-phase; and
c. 480Y/277—4 wire, 3-phase
with each plant using only one voltage.

Some of our equipment operates on single-phase; the rest requires three-phase. To simplify equipment purchasing and to facilitate interplant equipment transfers, I would like all equipment to operate on 480 volts. Is there anything I can do with transformers to help bring about voltage standardization?



A. In most electrical distribution systems, transformers are used to STEP DOWN a higher voltage to a lower voltage. But, with only a few exceptions, they can also be used to STEP UP a lower voltage to a higher voltage by means of a reverse connection: wiring the secondary terminals directly to the source voltage.

When a transformer is reverse connected, there is no reduction in KVA capacity. Likewise, impedance, efficiency and other characteristics remain unchanged. This makes them ideal for standardizing voltages to operate plant equipment.

Reverse connections are possible only when the primary-to-secondary voltage ratio is equal to the primary-to-secondary turns ratio. But, if there is ever any doubt, there are two rules to follow when reverse connecting transformers:

1. **Single-Phase—**Always use a transformer sized 1 KVA or larger. Sizes below 1 KVA may have compensation to develop approximately full voltage out of the secondary at full load, while the voltage at no load is slightly higher. When such a transformer is reverse connected to step up a voltage, the resulting full load voltage could be as much as 10% low. Normally, the smaller the transformer KVA, the greater the voltage compensation.
2. **Three-Phase—DO NOT** connect the neutral (Xo) of a "T" connected transformer to the source voltage neutral. If the supply voltages are not all equal when the neutral is connected, the transformer will act as a voltage balancing device for the supply system. This could result in false loading, causing the transformer to operate at a high temperature, resulting in shortened life. Usually, sizes below 15 KVA are "T" connected.

The chart to the left outlines the types of transformers and connections required to achieve voltage standardization throughout your company's plants.

ACHIEVING VOLTAGE STANDARDIZATION WITH TRANSFORMERS

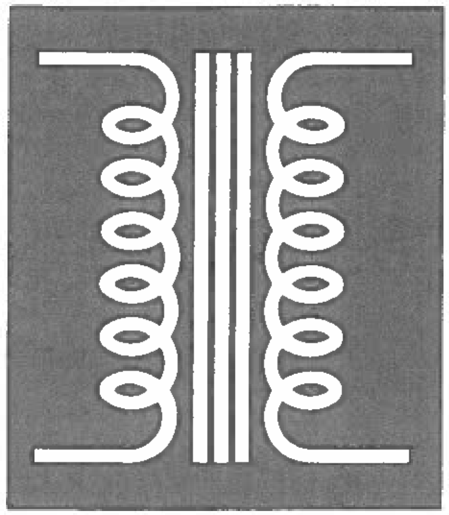
FACILITY SUPPLY VOLTAGE	SERVICE REQUIRED	TYPE OF TRANSFORMER	TYPE OF CONNECTION
208Y/120 4 wire - 3Ø	480V - 3Ø	480V Δ PRI - 208Y/120V SEC THREE PHASE	Reverse
240 3 wire - 3Ø	480V - 3Ø	480V Δ PRI - 240V Δ SEC THREE PHASE	Reverse
480Y/277 4 wire - 3Ø	480V 3Ø	None Required	Connect equipment to three supply lines. Neutral not used.
208Y/120 4 wire - 3Ø	480V - 1Ø	240 X 480 PRI 120/240 SEC SINGLE PHASE	Connect primary for 480V, secondary for 120V. Then connect 120V terminals to any line and neutral of supply.
240 3 wire - 3Ø	480V - 1Ø	240 X 480 PRI 120/240 SEC SINGLE PHASE	Connect primary for 480V, secondary for 240V. Then connect 240V terminals between any two lines of supply.
480Y/277 4 wire - 3Ø	480V - 1Ø	None Required	Connect equipment between any two lines of supply voltage.

no. 5 in a series

Interchange II

solutions to common transformer problems

Q. I am doing the electrical design work for the lighting of a large shopping mall. Each of the fixtures is 120 volts single-phase, and the incoming power is 480 volts three-phase. Our local utility recommends balancing the load on all three phases. I know I need a transformer to step down the 480V supply to 120V. Do I need a separate transformer (or possibly one that changes phases) to change the single-phase lighting load so it appears on the 480V supply as a balanced three-phase load?



A. A transformer will not change single-phase to three-phase, nor will it operate a single-phase load from a three-phase source and spread the load evenly over all three phases. Even phase changing transformers, which are suitable for changing two-phase to three-phase and vice versa, cannot help.

When a single-phase load is placed on a transformer's secondary, it returns to the transformer's primary as a single-phase load. This occurs whether the transformer is single-phase or three-phase. And that's why your local utility recommends balancing the load on all three phases: it allows them to maximize the efficiency of their equipment by keeping each phase of the three-phase system operating at equal loading.

The most practical means of balancing a single-phase load on all three,phases is to subdivide the load into three equal parts, then let each phase operate one-third of the total load. (This obviously will not work if it is impossible to subdivide the load.) Since your lighting load is comprised of several single-phase loads, it can be balanced by using one three-phase transformer rated primary 480VΔ, secondary 208Y/120 volts or three single-phase transformers rated primary 240X480 volts, secondary 120/240 volts. Figure 1 illustrates the connection necessary when using one three-phase unit. If three single-phase units were used, they would be field connected in the same configuration. In either case, 120V power for the lights would be distributed through a three-phase, four-wire lighting panel with 208 volts single-phase and three-phase also available.

An alternate way for you to achieve balanced three-phase loading is by using three single-phase transformers rated primary 240X480 volts, secondary 120/240 volts each supplying a single-phase, three-wire lighting panel as shown in Figure 2. In addition to the 120 volts, 240 volts would also be available.

Figure 1

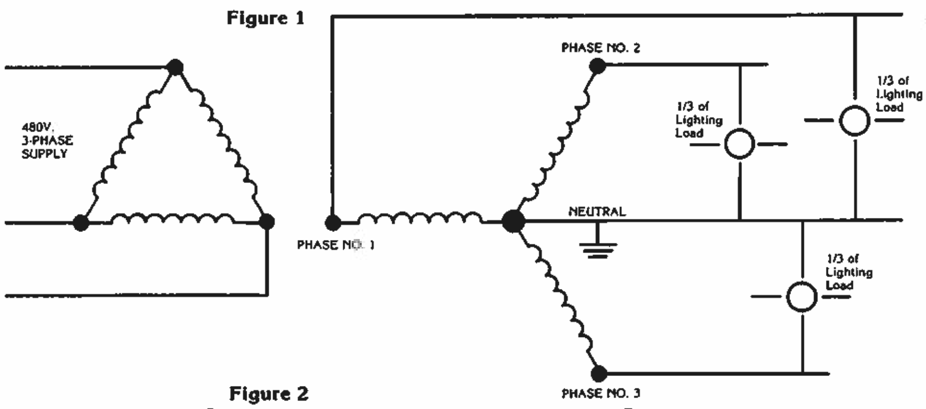
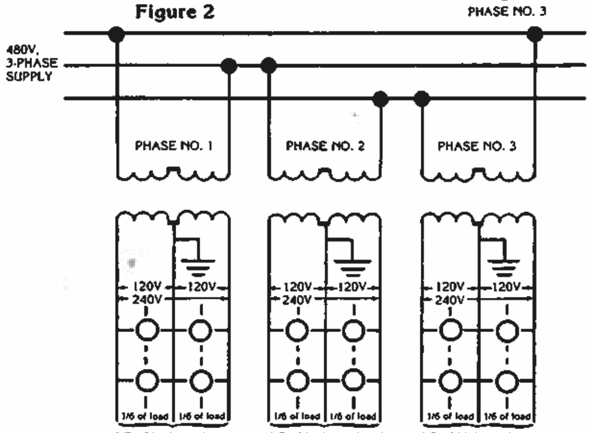


Figure 2



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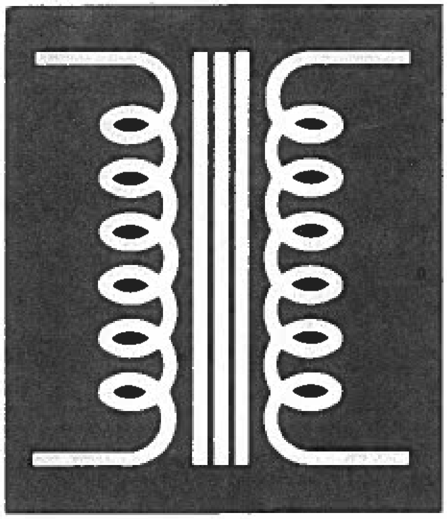
Q. I am designing the power distribution system of a large manufacturing complex. Incoming power is supplied at 480Y/277V, three phase and is distributed throughout the building at this voltage. Three-phase dry type transformers, 15 KVA through 500 KVA, are used to change the 480 volts to 240 volts for three-phase plant equipment, and to 208Y/120V for three-phase 208V motors and 120V lighting.

This manufacturing complex uses a great number of single-phase transformers for operating 120V work place lighting and 240V for manufacturing assembly tools. Because of model changes, it is often necessary to rearrange machinery on short notice. For example, we just replaced a machine operated by a 30 KVA, three-phase transformer with one requiring a 150 KVA, three-phase transformer.

The electrical distributors I work with usually stock most KVA sizes of single-phase transformers. However, several sizes of three-phase transformers are available only from a factory warehouse, causing serious delays in manufacturing schedules.

Is it practical to use single-phase transformers for the above three-phase applications?



A. It is very practical to use single-phase transformers for three phase applications. "Banking," as it is often referred to, involves no more than changing each phase voltage of the three-phase system using three single-phase transformers.

For the standard delta and wye connections indicated in your application, the capacity of the single-phase transformer to be used is one-third of the total three-phase requirement. For example, your new machine requiring 150 KVA could be serviced by three 50 KVA single-phase transformers.

When banking single-phase transformers, each unit should exhibit the same characteristics (KVA ratings, impedance and voltage ratios are of particular concern). The simplest way to avoid problems associated with transformer banking is to be certain all transformers are supplied by the same manufacturer and have identical catalog numbers.

The incoming power specified (480Y/277V) can be changed to the voltages required in your complex (240VΔ or 208Y/120V) by using standard single-phase transformers rated—primary: 240X480V and secondary: 120/240V. To obtain a 240VΔ output, connect the transformers as shown in Figure 1. Notice the single-phase transformer primaries are connected in series (480V). Their secondary windings are also connected in series (240V).

The necessary connection to obtain a 208Y/120V output utilizing the same single-phase transformers is shown in Figure 2. Here the primaries of the single-phase transformers are connected in series (480V), while their secondary windings are connected in parallel (120V). For the connections shown in Figures 1 and 2, the neutral or 4th wire of the 480Y/277V supply is not connected to the transformers.

FIGURE 1
SUPPLY POWER: 480Y/277V 4 WIRE
DESIRED OUTPUT: 240VΔ 3 WIRE

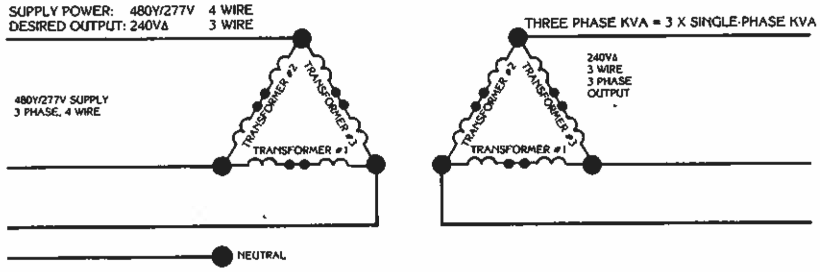
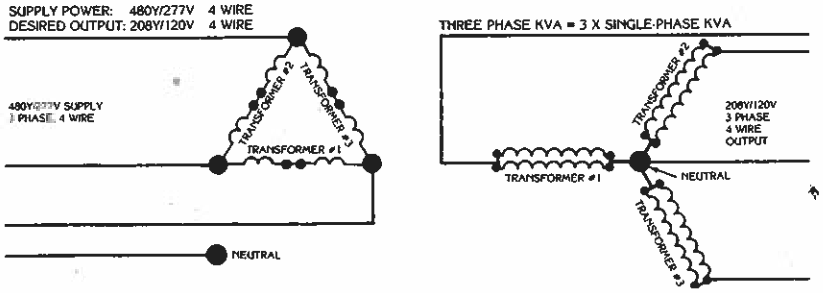


FIGURE 2
SUPPLY POWER: 480Y/277V 4 WIRE
DESIRED OUTPUT: 208Y/120V 4 WIRE



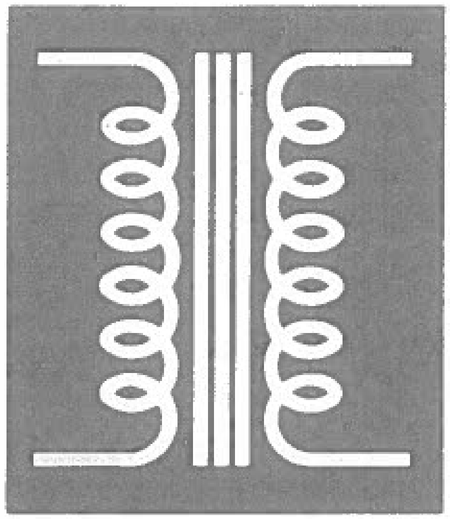
no. 7 in a series

Interchange II

solutions to common transformer problems

Q. As a design engineer, I am responsible for specifying and locating transformers in structures such as motels, hotels, industrial plants and office buildings.

I know transformer efficiencies approach 97%, but they still generate some heat. Should I give special attention to ventilation when locating transformers in an enclosed area?



A. All transformers generate heat as a by-product of their operation. The amount of heat generated can be determined by subtracting efficiency (expressed as a percentage) from 100% and multiplying that by the transformer's KVA rating. For example, a 100 KVA transformer operating at 97% efficiency would generate 3 kilowatts of heat (3% X 100 KVA). Since one KW represents 3,412 BTU's/hour, this transformer generates 10,236 BTU's/hour when operating at full load.

If not removed from the vicinity of the transformer, this heat can cause the transformer to operate at a higher than normal temperature. Such operation can significantly shorten the transformer's useful life.

NEMA Standard No. ST-20, Part 5.02 specifies: "Equipment conforming to these standards shall be capable of operating at nameplate rating, provided the average ambient temperature for any 24-hour period does not exceed 30°C, and the maximum ambient temperature does not exceed 40°C." Obviously, provisions must be made for ventilating an enclosed area where the transformer(s) are located, or the ambient could greatly exceed the NEMA limitations. Heat removal by natural convection is commonly accomplished as shown in Figure 1.

To size the openings, allow a minimum of 75 square inches per opening for each KW of heat generated. The ceiling should be at least 4-5 feet higher than the top of the transformer(s). Inlet openings should be in or near the floor, and the outlet openings should be in or near the ceiling of the room.

When ventilation by convection is not practical, forced air movement can be used. For each KW of transformer heat generated, a minimum of 100 cubic feet of air per minute is required. Forced air should not be directed at the transformer(s). This could upset the natural "chimney effect" air movement within the transformer, causing it to operate with an excessive temperature rise.

In some installations, air conditioning provides the most practical way to remove heat. For each KW of transformer loss incurred during an hour, 3,412 BTU's of air conditioning capacity must be provided.

For installations, such as a furnace room, where it is impractical to keep the air temperature within NEMA guidelines, a larger transformer must be used.

Regardless of the heat removal method used, the prime consideration should be maintaining a maximum ambient air temperature of 40°C or less, and a 24-hour average ambient of 30°C or less.

VENTILATING A DRY-TYPE TRANSFORMER IN AN ENCLOSED AREA

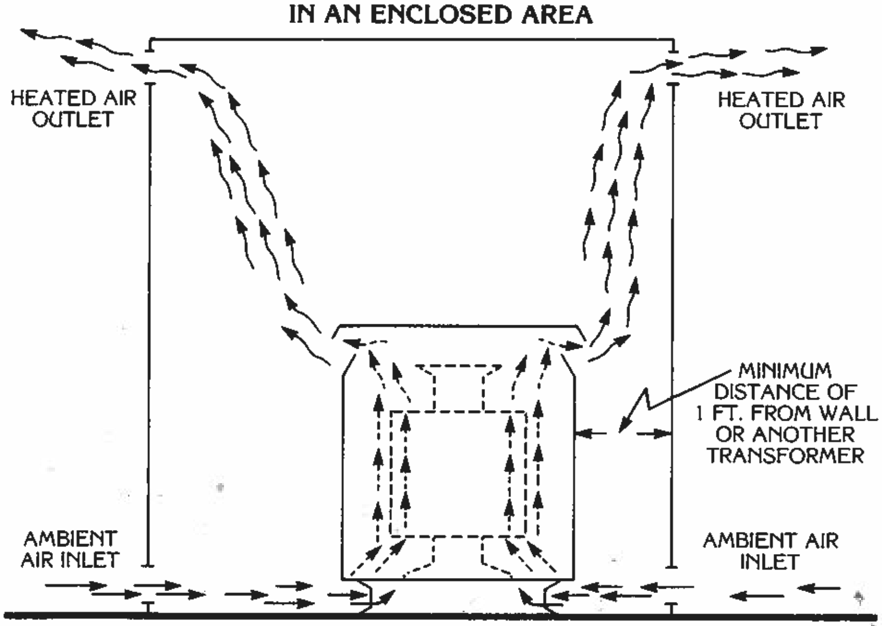


FIGURE 1

no. 8 in a series

Interchange II

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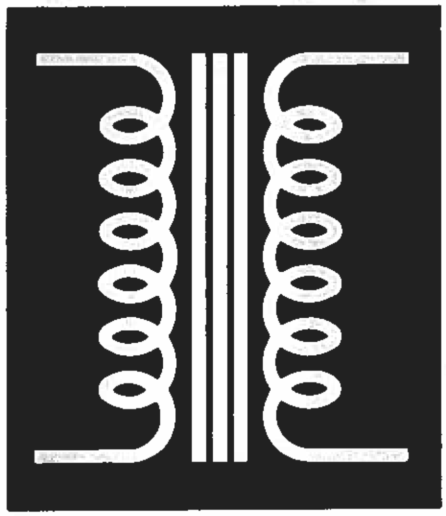
Q. I'm preparing to install some programmable controllers and a small office computer at the corporate headquarters of a large chemical manufacturer. The controllers will be located next to two mixers driven by variable-speed DC motors that obtain their power from silicon-controlled rectifiers. An electrically-heated curing oven is located in the same vicinity. The computer will be installed in the accounting department. Incoming power to the office complex and the production facility is 480V three-phase, 60 Hz.

I need transformers to reduce the incoming power to a usable voltage. Should I purchase conventional transformers or shielded ones?



A. Without saying so directly, you've expressed concern over possible equipment damage due to the transmission of unwanted electrical noise (spikes). These spikes can result from lightning surges on the power network, switching surges caused by the operation of other loads at the local site (e.g. start/stop motor operations), or even the operation of computer storage devices. Certainly, the nearby loads you mentioned would generate this type of interference, often causing microprocessor-controlled equipment to malfunction.

There are two types of electrical noise: (1) *transverse mode,* which appears between the supply lines, and (2) *common mode,* which appears between the supply lines and ground.

When a load is placed across the lines on which transverse mode noise appears, the noise is dissipated at its source. Therefore, transverse mode noise will cause you few, if any, problems.

Common mode noise, on the other hand, is transmitted to the transformer's output by capacitor action. The primary acts as one capacitor plate, the secondary as the other plate, and the ground provides a return path (see Figure 1). At this point, your concern becomes reality.

To prevent common mode noise from reaching the transformer's output, one of the capacitor plates must be turned into a ground. This is done during manufacturing by placing a metallic ground plane (shield) between the transformer's primary and secondary windings. The shield is connected to the ground plane, providing a drain path for eliminating unwanted electrical noise and spike voltages (see Figure 2). If the noise can't reach the secondary, it can't affect your sensitive loads.

Don't be fooled into thinking noise problems exist only in a production-type environment. It is equally important to shield sensitive equipment in an office location where electrical noise is generated by such things as typewriters, copiers and heating/cooling units.

UNSHIELDED TRANSFORMER

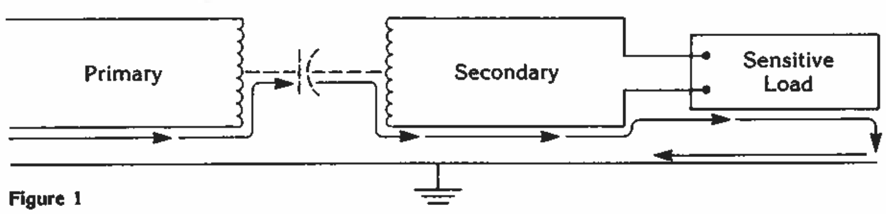


Figure 1

SHIELDED TRANSFORMER

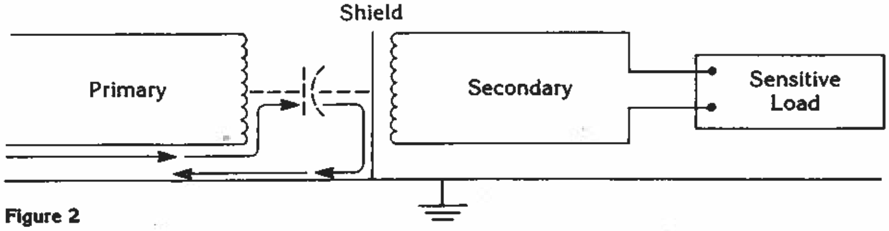


Figure 2

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Interchange II

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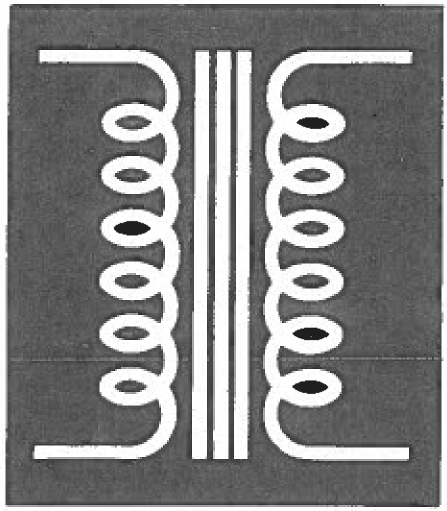
Q. Like a lot of electrical contractors, I don't work with transformers every day. Is there a checklist available which would assist me in the selection, installation and maintenance of dry-type transformers?

A. The following items represent "typical" points to consider when dealing with dry-type transformers.



SELECTION

1. SIZE (KVA): determined by the size of load (in KVA) the transformer will operate.
2. PHASES: single-phase loads may be operated with single or three-phase transformers (Note: balance loads); three-phase loads require three-phase transformers or a bank of three single-phase units.
3. LOCATION: outdoor transformers are suitable for indoor or outdoor installations; indoor transformers are for indoor installations only.
4. FREQUENCY: match the supply to the transformer.
5. PARALLEL OPERATION: be certain to match transformer characteristics such as KVA, impedance and voltage ratio; wherever possible, parallel like units by the same manufacturer; avoid paralleling an old unit with a new one.
6. CREDIBILITY: transformers should be listed by UL or CSA.

INSTALLATION

1. OVERCURRENT PROTECTION: refer to N.E.C. Article 450-3(b).
2. WIRE SIZE: conductors sized at least 125% of transformer full load current rating, or at least the same ampere rating as the overcurrent protection device.
3. ENVIRONMENTAL CONSIDERATIONS: provide adequate space for installation; avoid contaminated atmosphere; avoid locations where vibrations occur; avoid areas where explosive hazards exist; avoid locations where maintenance and inspection are difficult; avoid areas that could flood.
4. NOISE REDUCTION: mount on solid foundation; provide vibration isolators; use flexible conduit for connections; locate transformers away from quiet areas.
5. AIR TEMPERATURE: Maximum ambient temperature cannot exceed 40°C; 24-hour average ambient temperature cannot exceed 30°C.
6. ALTITUDE: most transformers are suitable for use up to 3300 feet; transformers can be used at higher elevations by reducing the KVA rating.
7. SURGE PROTECTION: transformer primary should be equipped with voltage surge protection.
8. GROUNDING: enclosure grounding—required by N.E.C. Article 300-9; transformer secondary grounding—refer to N.E.C. Article 250; ground wire must be of adequate ampere rating.
9. VENTILATION: provide minimum 1½ sq. ft. of inlet and outlet opening for each 100 KVA of transformer.
10. MECHANICAL: wall mounting bolts are to be of adequate size and strength.
11. FIELD WIRING: many transformers require wire rated higher than 60°C.
12. SPACING: ventilated transformers— allow minimum of 1 foot on all sides and top; non-ventilated— allow minimum of 6 inches from wall or ceiling; when located near combustibles, check N.E.C. Article 450-21 and 450-22.
13. UNIT VERIFICATION: be certain it's the right unit for the job by checking KVA, primary and secondary voltages, frequency, number of phases and taps.

MAINTENANCE

1. PERIODIC INSPECTION: (before inspection, be sure to disconnect primary power switch and label it "out of service;" ground the input and output terminals); inspect for clogged coil ventilators; clean insulators used for terminals and tap changers; check all electrical connections; inspect for moisture; check ground connections; check for need of painting enclosure; confirm enclosure has screen covers over openings; confirm all covers are firmly in place.
2. PROTECTION: (refer to N.E.C. Article 450-7) make sure all enclosure parts are non-combustible and moisture resistant; enclosure should provide reasonable protection against entry of foreign objects; exposed live parts should be properly protected; warning label should show voltages involved.
3. PROLONGED SHUTDOWN: install strip heaters or equivalent to prevent moisture condensation.

Acme Transformer has augmented the above information and compiled it into a pocket reference guide. For your FREE copy, circle the reader service number.

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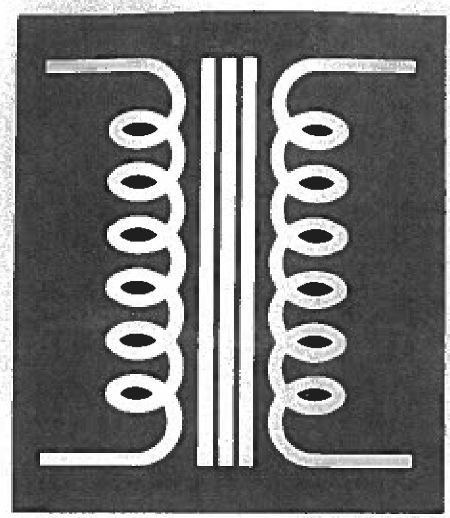

Q. **I often specify dry-type transformers and other electrical equipment for use in factories. Until now, all my projects have been in the Midwest.**

One of my clients is about to build two new plants: one located in the Rocky Mountains, the other in the desert Southwest. Elevations vary from 200 to 8300 feet above sea level, and the ambient air varies from −40°F (−40°C) to 110°F (43°C).

When sizing and selecting transformers for these plants, should the variations in ambient temperature and elevation be taken into consideration?

A. A dry-type transformer may be used at nameplate rating without restrictions, provided the following conditions are met:

1. It is operated in altitudes ranging from sea level to 3300 feet (1000 meters);
2. The maximum ambient air does not exceed 40°C (140°F) and the 24-hour average ambient does not exceed 30°C. (There is no limitation on how low the ambient may be.)

Several of your project requirements go beyond these limits. Higher altitudes reduce air density and its cooling effect. Elevated ambients produce the same net effect on the transformer. The solution is to reduce the ampere load on the transformer and thus the amount of heat generated (Figures 1 and 2) or to develop a trade-off between elevation and ambient temperature (Figure 3). Either solution ensures that the transformer will not exceed its rated temperature rise and should have a normal life expectancy. (Refer to Interchange II, No. 1).

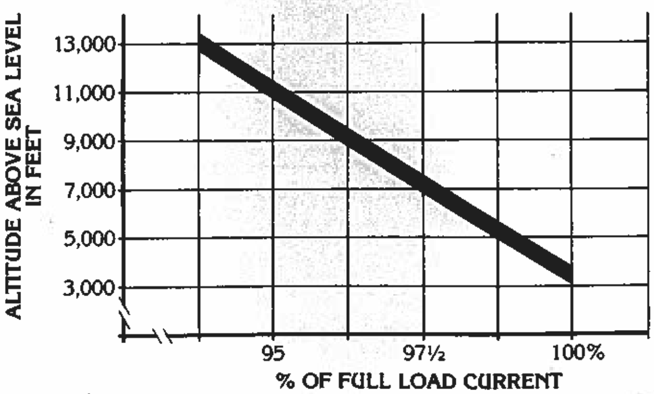

FIGURE I
Maximum loading of dry-type transformers at various altitudes when the 24-hour average ambient does not exceed 30°C.

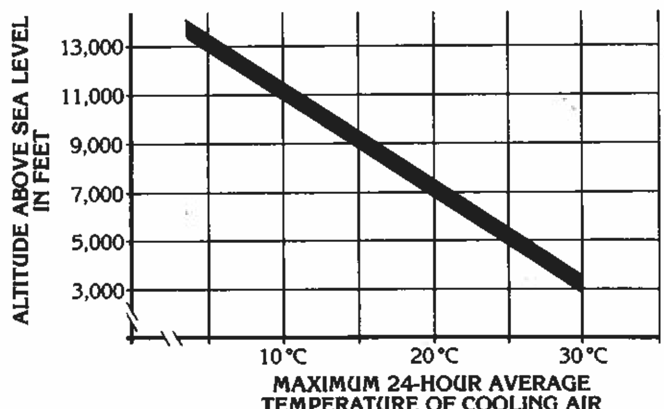

FIGURE III
A dry-type transformer may be operated at full load provided the average ambient air does not exceed the values shown for the various altitudes.

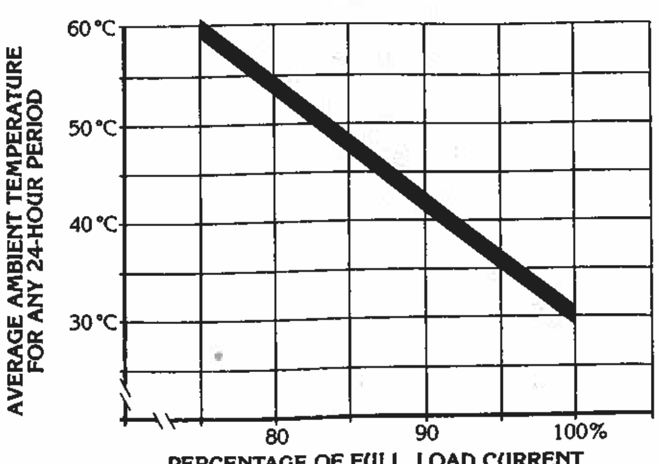

FIGURE II
Maximum loading of dry-type transformers when the 24-hour average ambient is above 30°C. Altitude is sea level to 3300 feet.

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Interchange II

solutions to common transformer problems

Q. I'm the chief engineer for a multi-plant manufacturer. Most of my work involves laying out and overseeing maintenance of all the electrical distribution systems. One problem that keeps coming up, regardless of plant location, is the variance of the voltages supplied by utilities. I realize they can't deliver power at exactly 600V, 480V or 240V, but some of our machinery needs specific voltages to operate properly. Can I use transformers to compensate for consistently high or low voltage?

A. Most utilities deliver voltages that fall within these recognized limits: 240V (216-252), 480V (432-504) and 600V (540-630). Since the transformer is a fixed voltage ratio device, the output voltage is always in direct proportion to the input voltage. If that ratio is 2:1 and the supply voltage is 480V, the output will be 240V. But if the supply voltage is 438V, the output will be only 219V.

High and low voltages can adversely affect different loads. (For a discussion on the effects of low voltage, refer to Interchange I . . . #2.) Therefore, care must be taken to deliver a voltage as close as possible to nominal. Consistently high or low voltage problems can be solved by using transformers equipped with primary taps.

Taps are nothing more than alternative terminals which can be connected to more closely match the supply voltage. These taps are arranged in increments of 2½% or 5% of the transformer's primary nominal ratings (see Figure 1). This provides an on-site adjustment so the transformer's primary matches the supply voltage and the secondary produces the desired voltage.

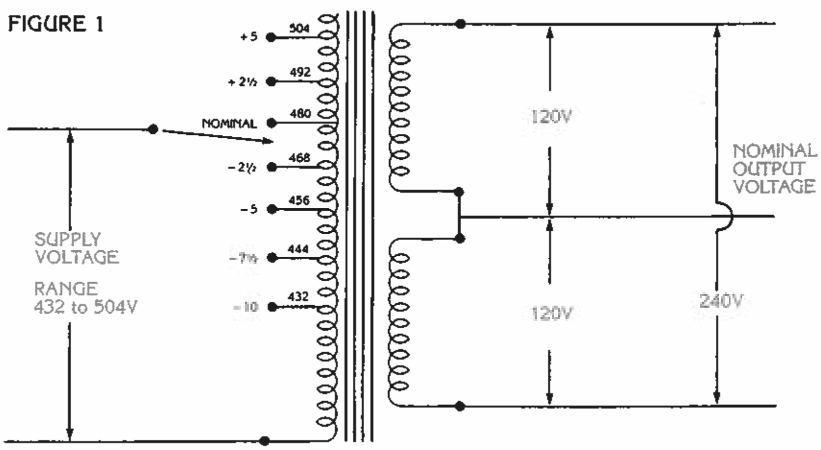
When using taps on a three-phase transformer, it's very important that the tap changers be set at the same position on all three coils (see Figure 2). If they are not, the following could result:

(1) output voltage on each of the three phases will not be equal, producing high unbalanced currents that will cause overheating or burnout of induction motors;

(2) if the transformer is connected primary Δ—secondary Δ, the resultant circulating current will create a false loading condition (refer to Interchange I . . . #10).

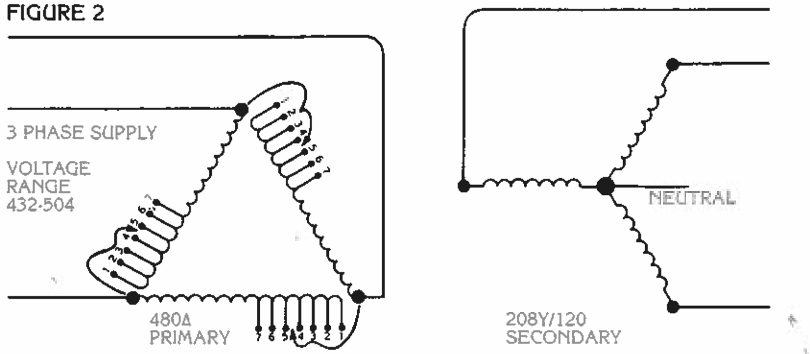
Just remember taps are for voltages that are **consistently** high or low. If the voltage varies frequently, taps are of no value.

FIGURE 1



SINGLE PHASE TRANSFORMER WITH PRIMARY TAPS

FIGURE 2



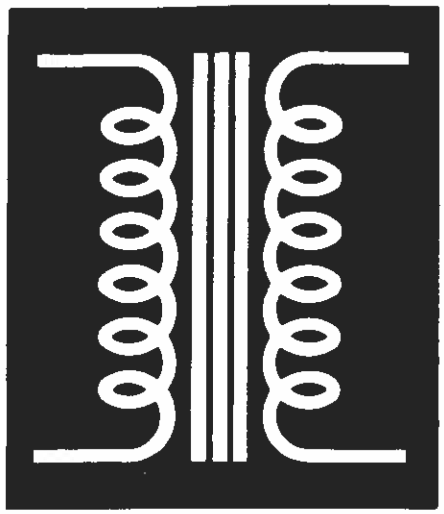
THREE PHASE TRANSFORMER WITH PRIMARY TAPS

no. 12 in a series

Interchange II

solutions to common transformer problems

Q. We just finished installing a 208Y/120 volt three-phase electrical system for a plastics manufacturer. The 120 volt service is used for lighting and small equipment; the 208 volt for motors and other power equipment. Yesterday, we relocated some 230 volt equipment into this same area. From past experience I know buck-boost transformers provide the most economical means of raising 208 volts to 230 volts, and I plan to use them. My problem is this: how is the ampere rating of the overcurrent protection device determined and where should it be located?



A. To determine the rating of an overcurrent protection device used on buck-boost transformers, you must first calculate full load input amps using these formulas:

$$1\Phi \text{ Full Load Input Amps} = \frac{1\Phi \text{ Buck-Boost KVA} \times 1000}{\text{Supply Voltage}}$$

$$3\Phi \text{ Full Load Input Amps} = \frac{3\Phi \text{ Buck-Boost KVA} \times 1000}{\text{Supply Voltage} \times 1.73}$$

When an isolating transformer is field connected to buck or boost a given voltage, the resulting KVA is different than the isolating unit's nameplate KVA. This KVA information is available from several transformer manufacturers. In your example, when three single phase 1 KVA isolating transformers are field connected to boost 208Y/120 volts 3Φ to 230 volts 3Φ, the combined 3Φ KVA is 33.20. Using this value in the formula, your three phase full load input amps comes to 92.26.

The generally accepted method for sizing transformer overcurrent protection devices is to multiply full load input amps by 125%, then round off to the next LARGER standard size. Again using your example, three phase full load input amps (92.26) multiplied by 125% yields a rating of 115.33 amps. Since this is not a standard overcurrent protection device rating, you would need to use the 125 amp rated device.

Refer to Figures I and II for the proper location of overcurrent protection devices on buck-boost transformers. By installing them on the transformer input, the devices will disconnect the unit(s) from the supply voltage in the event of a transformer malfunction. If the secondary conductors and load are coordinated to match the transformer's full load amp rating, additional secondary overcurrent protection is not required.

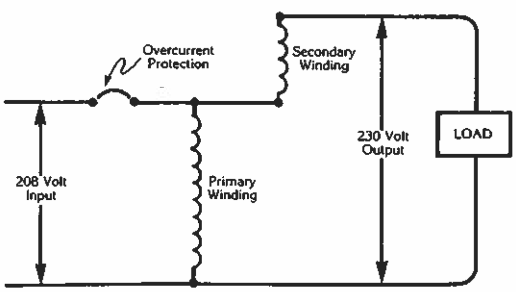


FIGURE I
Proper placement of overcurrent protection device on 1Φ buck-boost transformers.

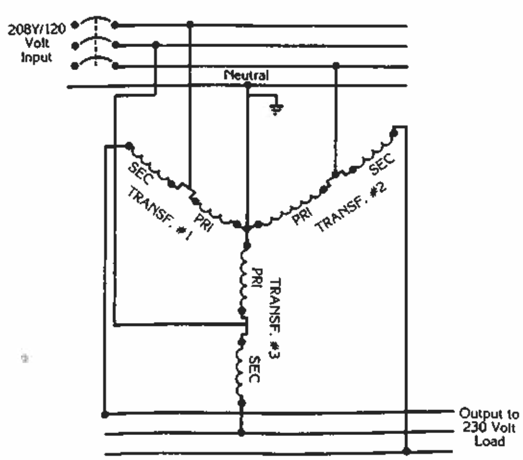


FIGURE II
Proper placement of overcurrent protection devices on 3Φ buck-boost transformers.